RESEÑA—REVIEW

ROTYLENCHULUS SPECIES: IDENTIFICATION, DISTRIBUTION, HOST RANGES, AND CROP PLANT RESISTANCE

A. F. Robinson,[1] R. N. Inserra,[2] E. P. Caswell-Chen,[3] N. Vovlas,[4] and A. Troccoli[4]

USDA, ARS, College Station, TX 77845, U.S.A.,[1] Department of Agriculture and Consumer Services, DPI, Nematology Section, Gainesville, FL 32614-7100, U.S.A.,[2] Department of Nematology, University of California, Davis, CA 95616 U.S.A.,[3] and Istituto Nematologia Agraria, CNR, via Amendola 165/A, 70126 Bari, Italy.[4]

ABSTRACT

Robinson, A. F., R. N. Inserra, E. P. Caswell-Chen, N. Vovlas, and A. Troccoli. 1997. *Rotylenchulus* species: Identification, distribution, host ranges, and crop plant resistance. Nematropica 27:127-180.

The ten known species of *Rotylenchulus* are sedentary root parasites that occur largely in tropical and subtropical latitudes. They can be distinguished with a simple dichotomous key. Hundreds of studies have examined the biology, economic impact, and management of the type species, *R. reniformis*. Information also is available regarding the geographical distribution, host range, and histopathology induced by *R. borealis, R. macrodoratus, R. macrosoma,* and *R. parvus.* Relatively little is known regarding *R. anamictus, R. brevitubulus, R. clavicaudatus, R. leptus,* and *R. sacchari. Rotylenchulus reniformis* and *R. parvus* both appear to have a cosmopolitan distribution in warm latitudes; *R. borealis,* so far, has been reported primarily from Europe and Africa; *R. macrodoratus* and *R. macrosoma* have been found primarily in the Mediterranean region. There are clear anatomical differences in the trophic site induced by *R. macrodoratus* (uninucleate giant cell) compared to those induced by *R. borealis, R. macrosoma, R. parvus,* and *R. reniformis* (syncytia). There also are differences in the abilities of these species to parasitize various hosts. *Rotylenchulus reniformis* appears to have the widest host range and has been reported to reproduce on 86% of 364 plant species examined. Many common weeds are good hosts. However, more than 50 crop or ornamental plants support little or no reproduction by most populations of *R. reniformis.* Examples include barley, maize, onion, rice, several crotalaria species, and resistant cultivars of soybean. Varying levels of resistance also have been found in cotton, olive, papaya, potato, sweet potato, tobacco, tomato, and various legumes. Most research on crop rotation and mixed cropping for management of *R. reniformis* has been done on cotton and soybean in the United States, and on legumes in India.

Key words: biology, crop rotation, distribution, host range, quarantine, reniform nematodes, *Rotylenchulus anamictus, Rotylenchulus borealis, Rotylenchulus brevitubulus, Rotylenchulus clavicaudatus, Rotylenchulus leptus, Rotylenchulus macrodoratus, Rotylenchulus macrosoma, Rotylenchulus parvus, Rotylenchulus reniformis, Rotylenchulus sacchari.*

RESUMEN

Robinson, A. F., R. N. Inserra, E. P. Caswell-Chen, N. Vovlas y A. Troccoli. 1997. Las especies de *Rotylenchulus*: Identificación, distribución, rangos de hospederos y resistencia de cultivos. Nematropica 27:127-180.

Las diez especies conocidas de *Rotylenchulus* son parásitos sedentarios de raíces y se encuentran principalmente en latitudes tropicales y subtropicales. Se pueden diferenciar con una simple clave dicotómica. La biología, la importancia económica y el control de la especie tipo, *Rotylenchulus reniformis,* han sido el objetivo de centenares de investigaciones. También se dispone de información sobre la distribución geográfica, el rango de hospederos y la histopatología inducida por *R. borealis, R. macrodoratus, R. macrosoma* y *R. parvus.* Se conoce poco sobre *R. anamictus, R. brevitubulus, R. clavicaudatus, R. leptus* y *R. sacchari.* La especies *R. reniformis* y *R. parvus* presentan una extensa distribución en latitudes cálidas. *Rotylenchus borealis* se encuentra principalmente en Europa y Africa, mientras que

R. macrodoratus y *R. macrosoma* se localizan en la región Mediterránea. *Rotylenchulus macrodoratus* induce la formación de una célula gigante mononucleada en la zona estelar de la raíz mientras que *R. borealis, R. macrosoma, R. parvus* y *R. reniformis* producen un sincitio. Existen diferencias entre las tasas de reproducción de *R. reniformis, R. parvus* y *R. borealis* en varios hospederos. *Rotylenchulus reniformis* parece tener un rango de hospederos más amplio que las otras especies de este género y se reproduce en 86% de las 364 especies de plantas examinadas. Muchas malezas comunes son buenos hospederos. Sin embargo, más de 50 plantas agronómicas y ornamentales permiten poca o ninguna reproducción de *R. reniformis.* Ejemplos incluyen arroz, cebada, cebolla, maíz, varias especies de crotalaria y cultivares resistentes de soya. Se encuentran también diferentes niveles de resistencia en el algodón, olivo, papaya, papa, batata, tabaco, tomate y varios cultivos leguminosos. La mayoría de las investigaciones sobre la rotación de cultivos para manejar poblaciones de *R. reniformis* han sido realizadas en algodón y soya en los Estados Unidos y en varios cultivos leguminosas en la India.

Palabras claves: biología, cuarentena, distribución, nemátodos reniformes, rango de hospederos, rotación de cultivos, *Rotylenchulus anamictus, Rotylenchulus borealis, Rotylenchulus brevitubulus, Rotylenchulus clavicaudatus, Rotylenchulus leptus, Rotylenchulus macrodoratus, Rotylenchulus macrosoma, Rotylenchulus parvus, Rotylenchulus reniformis, Rotylenchulus sacchari.*

INTRODUCTION

Reniform nematodes (*Rotylenchulus* spp.) are semi-endoparasites of roots and occur commonly in tropical and subtropical regions. The term "reniform" refers to the kidney-shape of the body of the sedentary mature female. Ten valid species of *Rotylenchulus* are known. *Rotylenchulus reniformis* is the most economically important and has the widest geographical distribution and host range. It was described in 1940 by Linford and Oliveira from specimens collected in Hawaii, U.S.A., and for more than 20 years was the only representative of the genus. In 1961, a second species, *R. parvus* (Williams, 1960), was transferred from the genus *Helicotylenchus* into the genus *Rotylenchulus* by Sher. In 1962, a third species, *R. borealis,* was described from The Netherlands by Loof and Oostenbrink. Five additional species from Africa (*R. anamictus, R. clavicaudatus, R. leptus, R. macrosoma,* and *R. variabilis*) and one from Italy, (*R. macrodoratus*) were described by Dasgupta *et al.* in 1968. *Rotylenchulus variabilis* was later synonymized with *R. borealis* (Germani, 1978a). Subsequently, two more species, *R. sacchari* (Van den Berg and Spaull, 1981) and *R. brevitubulus* (Van den Berg, 1990), have been described from South Africa.

Taxonomic descriptions for some *Rotylenchulus* species are incomplete; for instance, mature females of *R. anamictus, R. brevitubulus, R. leptus,* and *R. sacchari* are unknown. Also, type hosts of *R. anamictus, R. brevitubulus, R. clavicuadatus, R. leptus,* and *R. sacchari* were not determined. In the case of *R. clavicaudatus,* only one mature female was found in the rhizosphere of sugarcane (*Saccharum officinarum*), making the identity of the type host plant uncertain. Valid species of the genus *Rotylenchulus,* their type host(s), and the author(s) of each species description are listed in Table 1.

Type localities of known *Rotylenchulus* species (Table 1) reflect the largely tropical and subtropical distributions of these root parasites. Even *R. borealis,* which was originally found in The Netherlands, has been reported in several African countries where it was confused with *R. variabilis,* its junior synonym (Germani, 1978a). Although several reniform nematode species may ultimately prove to be important pests on some crops, *Rotylenchulus renifor-*

Table 1. Species of the genus *Rotylenchulus*.

Species	Type host	Type locality	Author(s)
*R. anamictus**	Associated with *Acacia*	Somalia	Dasgupta *et al.*, 1968
*R. brevitubulus**	Unknown	South Africa	Van den Berg, 1990
R. borealis	Maize (*Zea mays* L.)	The Netherlands	Loof & Oostenbrink, 1962
R. clavicaudatus	Associated with *Strelitzia* and sugarcane (*Saccharum officinarum* L.)	South Africa	Dasgupta *et al.*, 1968; Van den Berg & Spaull, 1981
*R. leptus**	Associated with bamboo (*Bambusa vulgaris* Schard. *ex* J. C. Wendl.)	Zimbabwe	Dasgupta *et al.*, 1968
R. macrodoratus	Grape (*Vitis vinifera* L.)	Italy	Dasgupta *et al.*, 1968
R. macrosoma	Olive (*Olea europaea* L.)	Israel	Dasgupta *et al.*, 1968; Cohn & Mordechai, 1988
R. parvus	Sugarcane (*S. officinarum*) and Upland cotton (*Gossypium hirsutum* L.)	Mauritius and California (USA)	Williams, 1960; Dasgupta *et al.*, 1968
R. reniformis	Pineapple [*Ananas comosus* (L.) Merril]	Hawaii (USA)	Linford & Oliveira, 1940
*R. sacchari**	Associated with sugarcane	South Africa	Van den Berg & Spaull, 1981

*Species with undescribed mature females.

mis is the only species proven so far to be economically important and it is by far the most intensely investigated. It has been the subject of numerous studies related to life cycle, host range, host-parasite relations, plant damage, behavior, survival, and management. Biological studies on other species are limited to *R. borealis*, *R. macrodoratus*, *R. macrosoma*, and *R. parvus*.

Life cycle: All *Rotylenchulus* species studied so far have a generally similar life cycle. One-celled eggs are oviposited by mature females. Embryogenesis is completed with the appearance of the first-stage juvenile (J1) which molts within the egg shell, producing the second-stage juvenile (J2) that emerges from the egg. The J2 and following juvenile stages (J3 and J4) are not parasitic and retain the cuticles of the previous stages after molting (Fig. 1). The body of *R. reniformis* is slightly shorter and smaller in volume rather than larger after each molt (Bird, 1983). Eight species of *Rotylenchulus* have both females and males (Dasgupta *et al.*, 1968; Van den Berg, 1990; Van den Berg and Spaull, 1981). In *R. reniformis*, the final molt gives rise to approximately equal numbers of vermiform parasitic females and nonparasitic males. *Rotylenchulus parvus* and some populations of *R. reniformis* reproduce parthenogenetically (Dasgupta and Raski, 1968; Nakasono, 1983). Most or all of the vermiform adults produced by the final molt in these populations are females; males are rare or absent.

In the presence of host roots, vermiform females penetrate the root cortex, establish a permanent feeding site in the stele and become sedentary (Fig. 2A,B). The anterior part of the body remains embedded in the root whereas the posterior portion protrudes from the root surface and swells during maturation of the reproductive system, assuming a kidney-like shape (Figs. 2D,E). In the stele, the infective females induce the formation of specialized trophic sites involving stelar tissues (Fig. 2D,E) (Cohn and Mordechai, 1977; Rebois *et al.*, 1975; Vovlas *et al.*, 1985). Soon after gonad maturation, females deposit eggs into a gelatinous matrix (Fig. 2E). The gelatinous egg matrix in *Rotylenchulus* species flows from the vulva (Fig. 3) and it is produced by vaginal glands (Sivakamur and Seshadri, 1971), in contrast to gelatinous matrix production by rectal glands in *Meloidogyne* species. The number of eggs found in an egg mass usually does not exceed 60 but can reach 200 (Sivakumar and Seshadri, 1971). Males are not parasitic (Fig. 2C).

Fig. 1. Fourth-stage juvenile of *Rotylenchulus macrodoratus* enveloped by two cuticles. Scale bar = 34 μm. (After Inserra and Vovlas, 1980).

The timing of developmental events varies with species, as well as with temperature (Bird, 1984; Heald and Inserra, 1988;

Fig. 1. Fourth-stage juvenile of *Rotylenchulus macrodoratus* enveloped by two cuticles. Scale bar = 34 µm. (After Inserra and Vovlas, 1980).

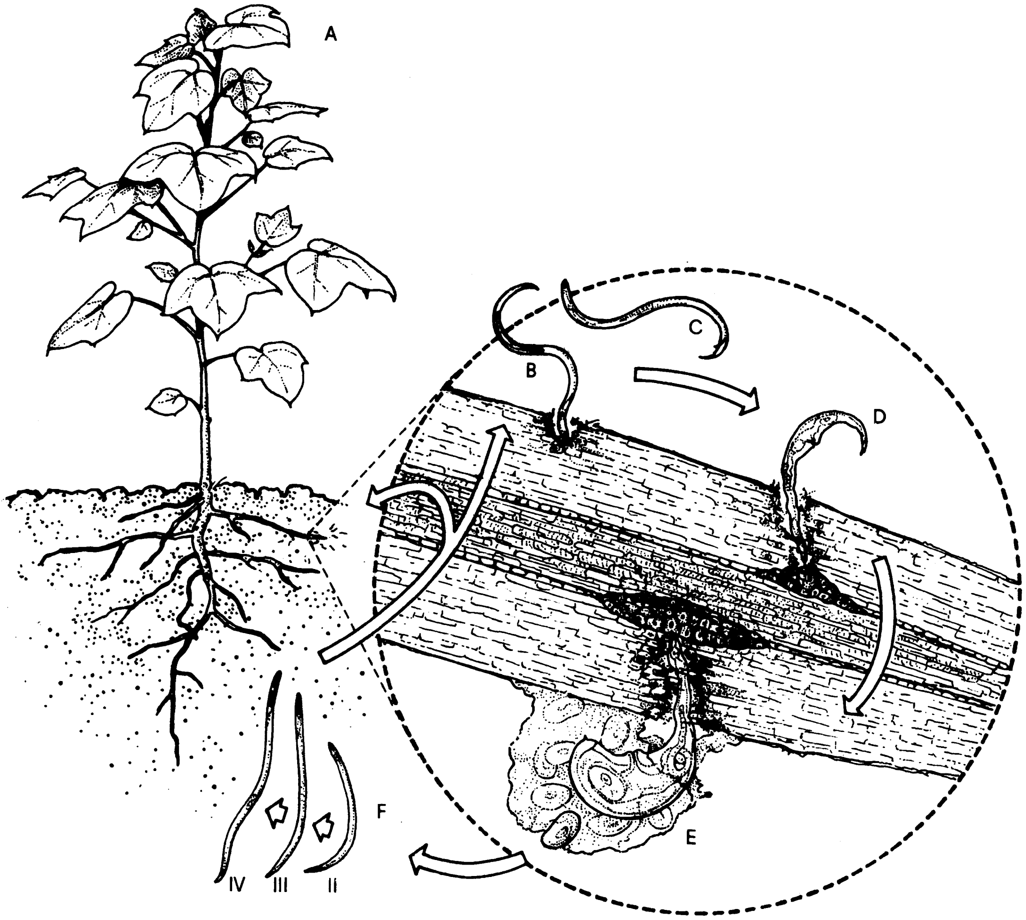

Fig. 2. Life cycle of *Rotylenchulus reniformis* on cotton. A) Cotton plant growing in soil infested by reniform nematodes. B) Immature vermiform female penetrating with the anterior portion of the body into a feeder root. C) Non-parasitic male. D) Female in more advanced stage of gonad maturation and establishing a permanent feeding site in the stele of the root. E) Mature female feeding on a stelar syncytium and producing eggs in the gelatinous matrix, which surrounds the swollen posterior portion of the body protruding from the root surface. F) Second, third, and fourth-stage juveniles in the soil.

Rebois, 1973) and host (Bishnoi and Yadav, 1989), but typically eggs hatch 1-2 weeks after being laid, and the infective stage is reached 1-2 weeks after hatch. Once root penetration occurs, 1 or 2 more weeks are required for females to reach reproductive maturity; in the absence of a host, however, vermiform stages in the soil can remain in a state of arrested development indefinitely. The life cycle can be shorter than 3 weeks or can last more than 2 years if a host is not present and the soil remains dry. Additional details on the life cycle of *R. reniformis* are summarized by Gaur and Perry (1991b) and by Sivakumar and Seshadri (1971).

Identification: Rotylenchulus species belong to the subfamily Rotylenchulinae, in the family Hoplolaimidae. Identification of the genus is based mainly on mor-

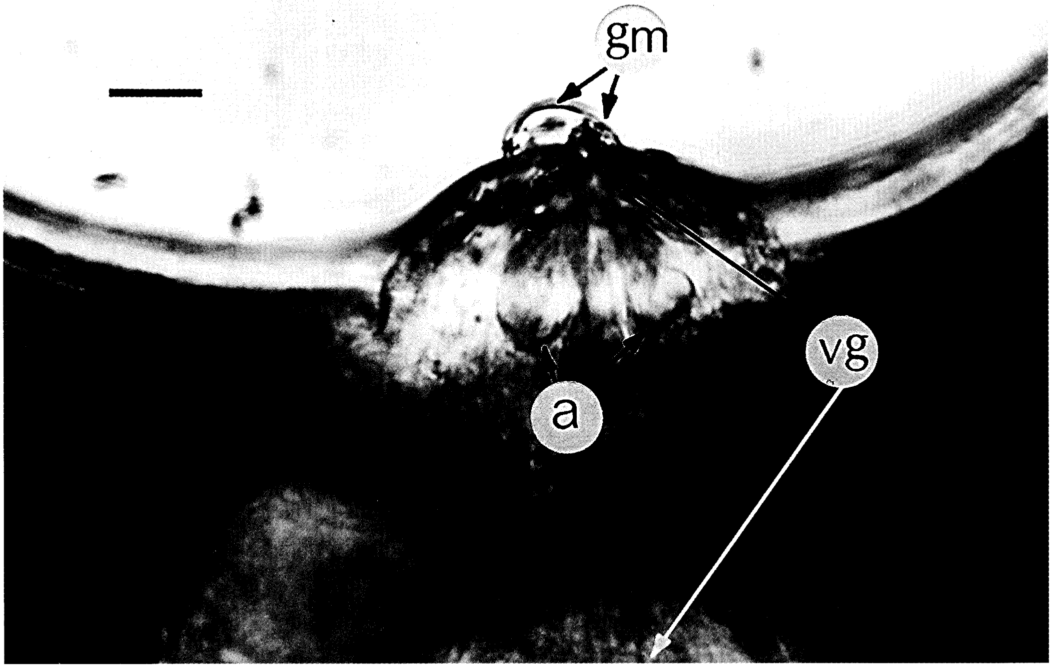

Fig. 3. *Rotylenchulus reniformis* mature female. Lateral view of the vulval area showing two droplets of gelatinous matrix (gm) flowing from the vulva (not visible in lateral view). Note the ampullae (a) where the gelatinous matrix secreted by the vaginal glands (not visible) accumulates. vg = vagina. Scale bar = 7 µm.

phological characters of vermiform females (Fig. 4). Morphological characters of swollen females and the presence or absence of males are useful for the separation of *Rotylenchulus* species. A simple key to the species of *Rotylenchulus* was proposed by Germani (1978a). We provide a modified version of this key.

Key to the species of the genus Rotylenchulus *based on morphological characteristics of immature females.*[†]

1. Stylet > 27 µm .... *R. sacchari*
Stylet = 10-15 µm 2
Stylet = 16-26 µm (males present) 5
2. Males present 3
Males absent or rare 4
3. V = 55-66% .... *R. borealis*
V = 67-72% .... *R. anamictus*
4. Head conoid, truncate .... *R. leptus*
Head rounded .... *R. parvus*
5. V = 55-63% 6
V > 63% 7
6. Tail with clavate terminus ....
.... *R. clavicaudatus*
Tail with bluntly rounded terminus .....
.... *R. macrosoma*

[†] *Rotylenchulus brevitubulus* is omitted from the key because second-stage juveniles of this species have a bifurcate tail terminus completely unlike other *Rotylenchulus* spp. Furthermore, in *R. brevitubulus* vermiform females the distance between the dorsal esophageal gland orifice and the base of stylet knobs is shorter (<10 µm) than that (>10 µm) of other *Rotylenchulus* species.

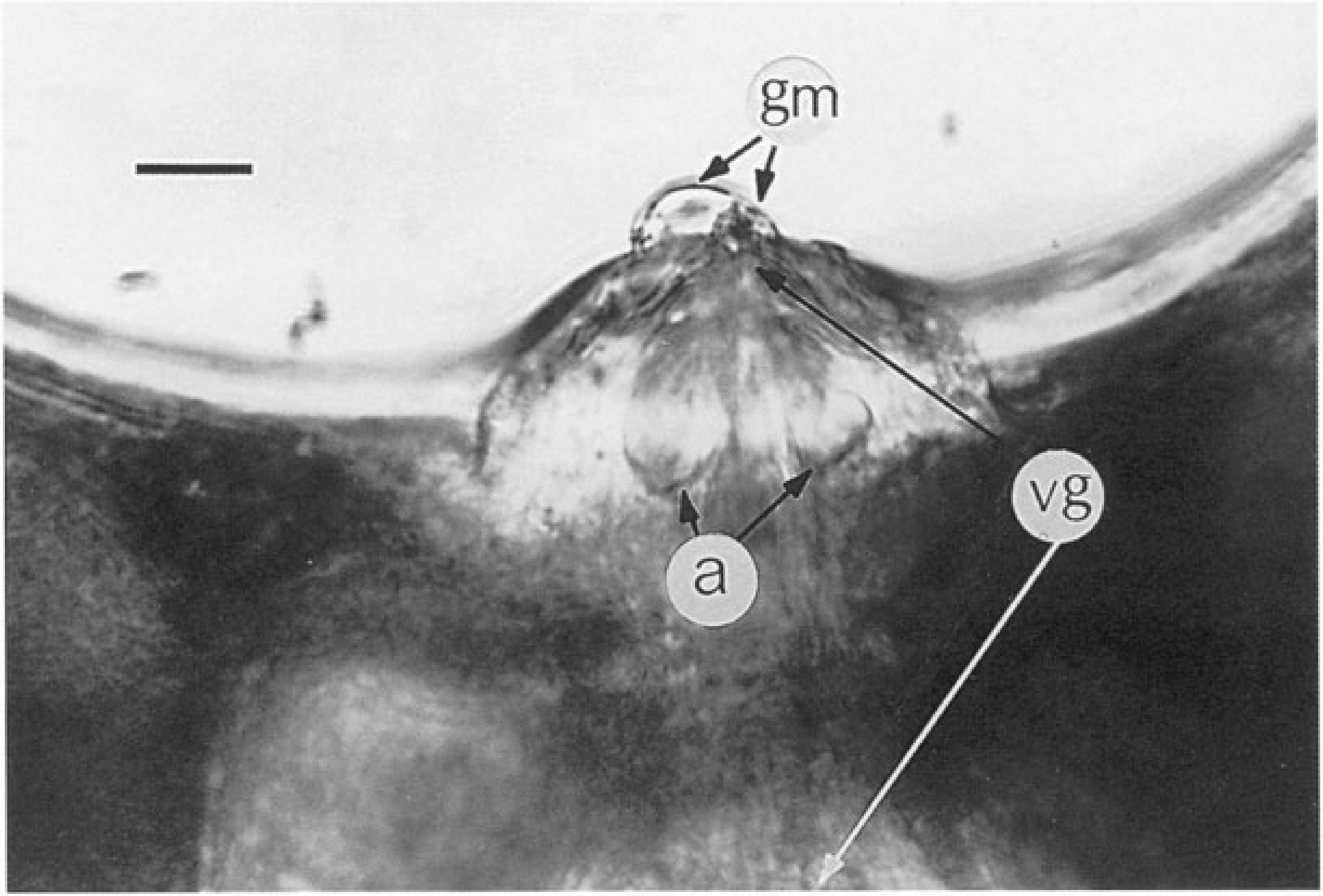

Fig. 3. *Rotylenchulus reniformis* mature female. Lateral view of the vulval area showing two droplets of gelatinous matrix (gm) flowing from the vulva (not visible in lateral view). Note the ampullae (a) where the gelatinous matrix secreted by the vaginal glands (not visible) accumulates. vg = vagina. Scale bar = 7 µm.

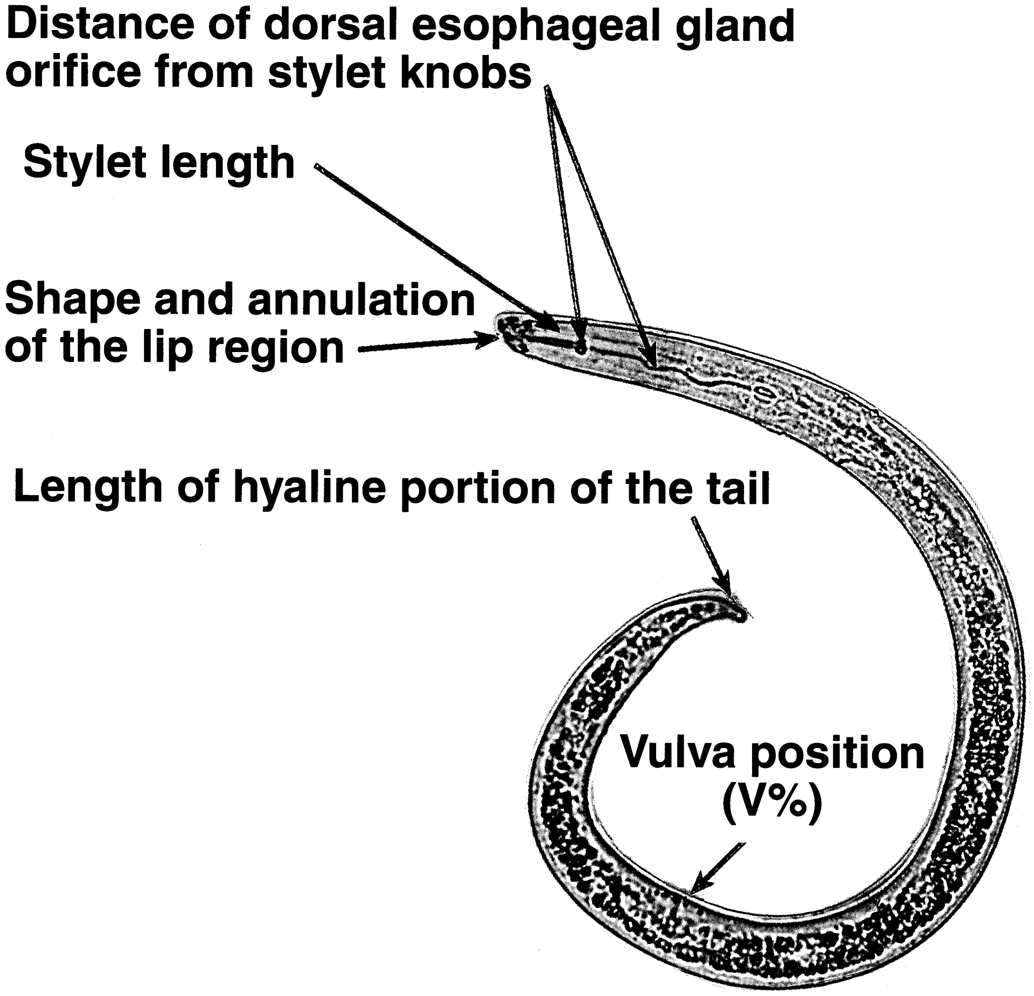

Fig. 4. Illustration of a *Rotylenchulus reniformis* immature female showing the major morphological characters of diagnostic value for separating *Rotylenchulus* species.

7. Stylet = 16-21 µm .... *R. reniformis*
   Stylet = 22-26 µm .... *R. macrodoratus*

Vermiform females of *R. anamictus, R. borealis, R. leptus,* and *R. parvus* have a shorter stylet (15 µm or less) than that (16 µm or more) of *R. clavicaudatus, R. macrodoratus, R. macrosoma,* and *R. reniformis.* However, populations of *R. borealis* with a stylet length of 16 µm have been reported from The Netherlands. For these populations other morphological characters of diagnostic value, such as the position of the vulva, which is more anterior (V = 57-60%) than in *R. reniformis,* should be used. Dasgupta *et al.* (1968) proposed the separation of *Rotylenchulus* species into five groups differing in the shape of the lip region and length of the hyaline portion of the tail (Fig. 5).

Parasitic habits and pathology: Information on parasitic habits of reniform nematodes and the pathology caused by them is

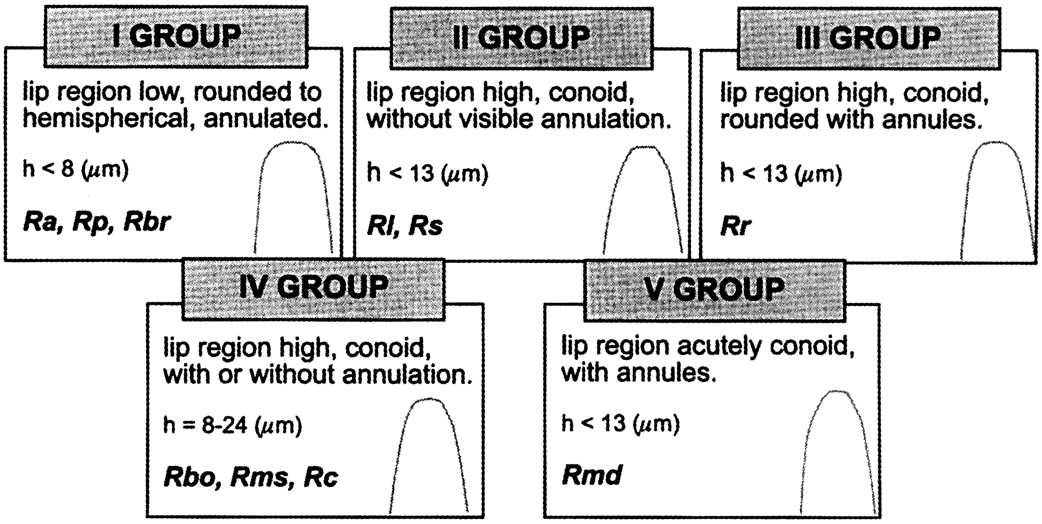

Fig. 5. Morphological groups of species, based on lip morphology and length of hyaline portion of tail (h), proposed by Dasgupta *et al.*, 1968 and updated in 1996 for the genus *Rotylenchulus*. *Ra* = *R. anamictus*, *Rbo* = *R. borealis*, *Rbr* = *R. brevitubulus*, *Rc* = *R. clavicaudatus*, *Rl* = *R. leptus*, *Rmd* = *R. macrodoratus*, *Rms* = *R. macrosoma*, *Rp* = *R. parvus*, *Rr* = *R. reniformis*, and *Rs* = *R. sacchari*.

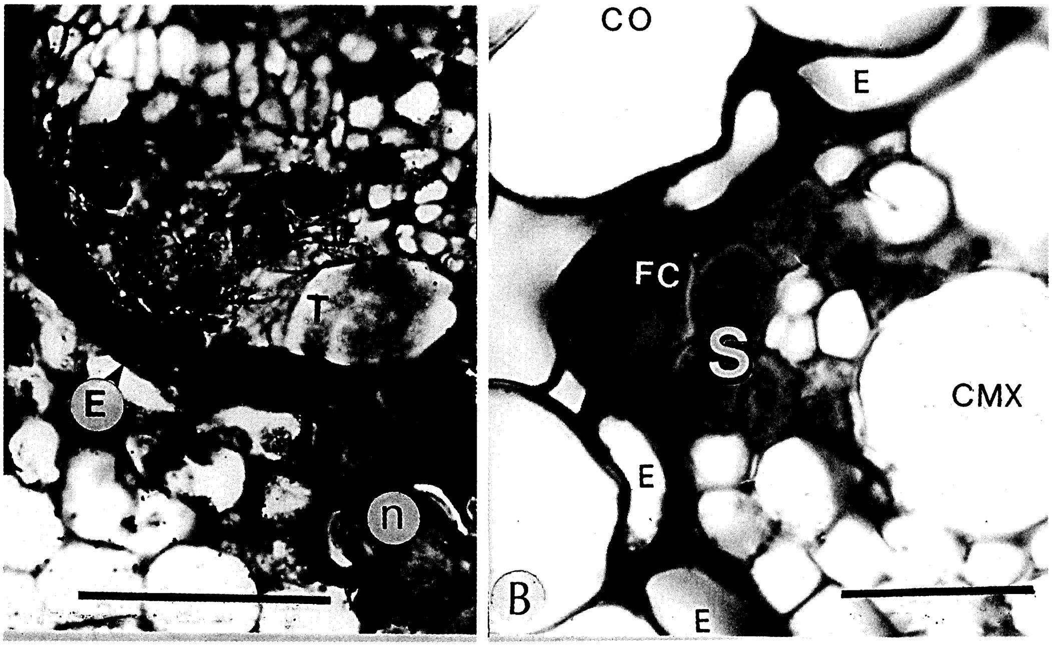

Fig. 6. Trophic sites induced by reniform nematode species. A) Cross section of a *Vitis vinifera* root showing a *Rotylenchulus macrodoratus* female (n) with the stylet inserted through the wall of an endodermal cell (E) and initiating the formation of a trophic site (uninucleate giant cell) (T) in the stele. B) Cross section of a *Zea mays* root showing a trophic site (stelar syncytium) (S) induced by *Rotylenchulus borealis*. Note the syncytium expanding from a feeding cell (FC) adjacent to the endodermis (E) in the pericycle and vascular parenchyma. CO = cortical parenchyma. CMX = metaxylem element. Scale bars = 50 μm in A and 25 μm in B. (After Inserra and Vovlas, 1980; Vovlas and Inserra, 1982).

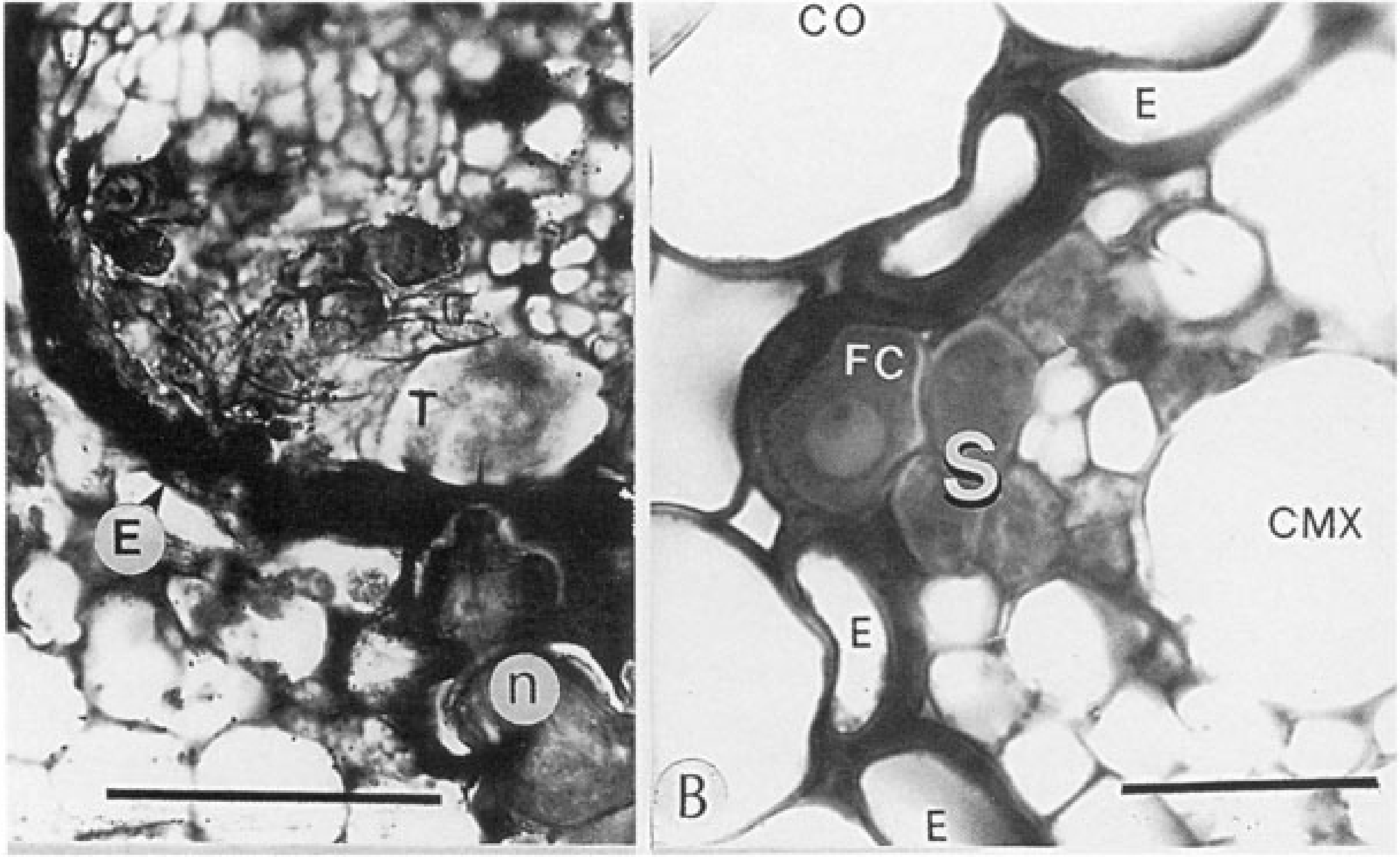

Fig. 6. Trophic sites induced by reniform nematode species. A) Cross section of a *Vitis vinifera* root showing a *Rotylenchulus macrodoratus* female (n) with the stylet inserted through the wall of an endodermal cell (E) and initiating the formation of a trophic site (uninucleate giant cell) (T) in the stele. B) Cross section of a *Zea mays* root showing a trophic site (stelar syncytium) (S) induced by *Rotylenchulus borealis*. Note the syncytium expanding from a feeding cell (FC) adjacent to the endodermis (E) in the pericycle and vascular parenchyma. CO = cortical parenchyma. CMX = metaxylem element. Scale bars = 50 µm in A and 25 µm in B. (After Inserra and Vovlas, 1980; Vovlas and Inserra, 1982).

available for only five of the ten species. The histopathological changes they induce have been studied in numerous plants by observing serial sections of root tissue under the transmission electron or compound light microscope. *Rotylenchulus borealis* has been studied on both *Ipomoea batatas* and *Zea mays* (Fig. 6B) (Vovlas and Inserra, 1982; Vovlas *et al.*, 1985), *R. macrosoma* on *Glycine max* (Cohn and Mordechai, 1988), *R. parvus* on *S. officinarum* (Vovlas *et al.*, 1985), and *R. macrodoratus* on seven hosts, including *Dianthus barbatus* (Inserra and Vovlas, 1980), *Ficus carica* (Fig. 7A) (Inserra and Vovlas, 1980), *G. max* (Cohn, 1976), *Olea europaea* (Fig. 7B) (Vovlas and Inserra, 1976), *Pistacia vera* (Fig. 7C) (Vovlas, 1983), *Quercus calliprinos* (Cohn, 1976), and *Vitis vinifera* (Fig. 6A) (Vovlas and Vlachopoulos, 1991). Other histopathological studies have examined *R. reniformis* on more than 20 crop species,

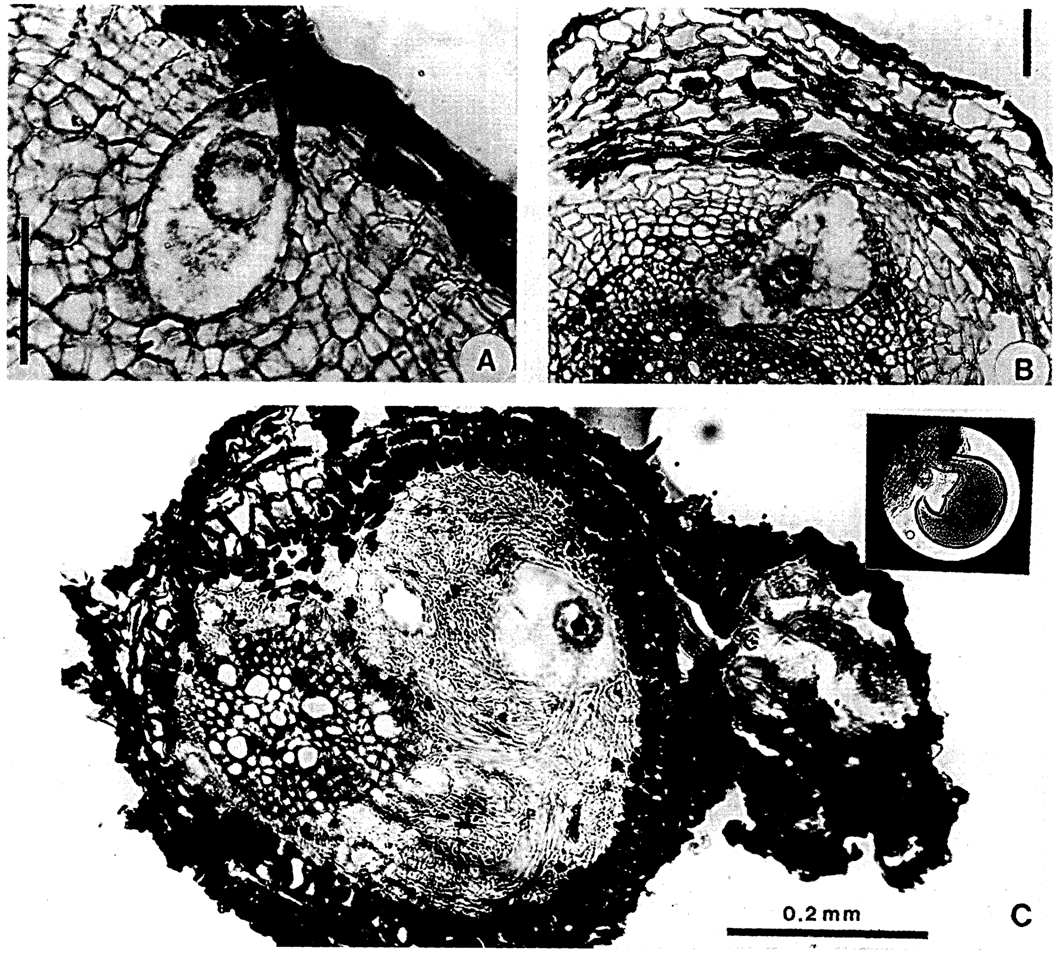

Fig. 7. Trophic sites induced by *Rotylenchulus macrodoratus*. Nematode-infected cross sections of *Ficus carica* (A), *Olea europaea* (B), and *Pistacia vera* (C) roots showing an uninucleate giant cell with hypertrophied nucleus and prominent nucleolus in the stele. Scale bars in A and B = 50 µm. (After Inserra and Vovlas, 1980; Vovlas, 1983).

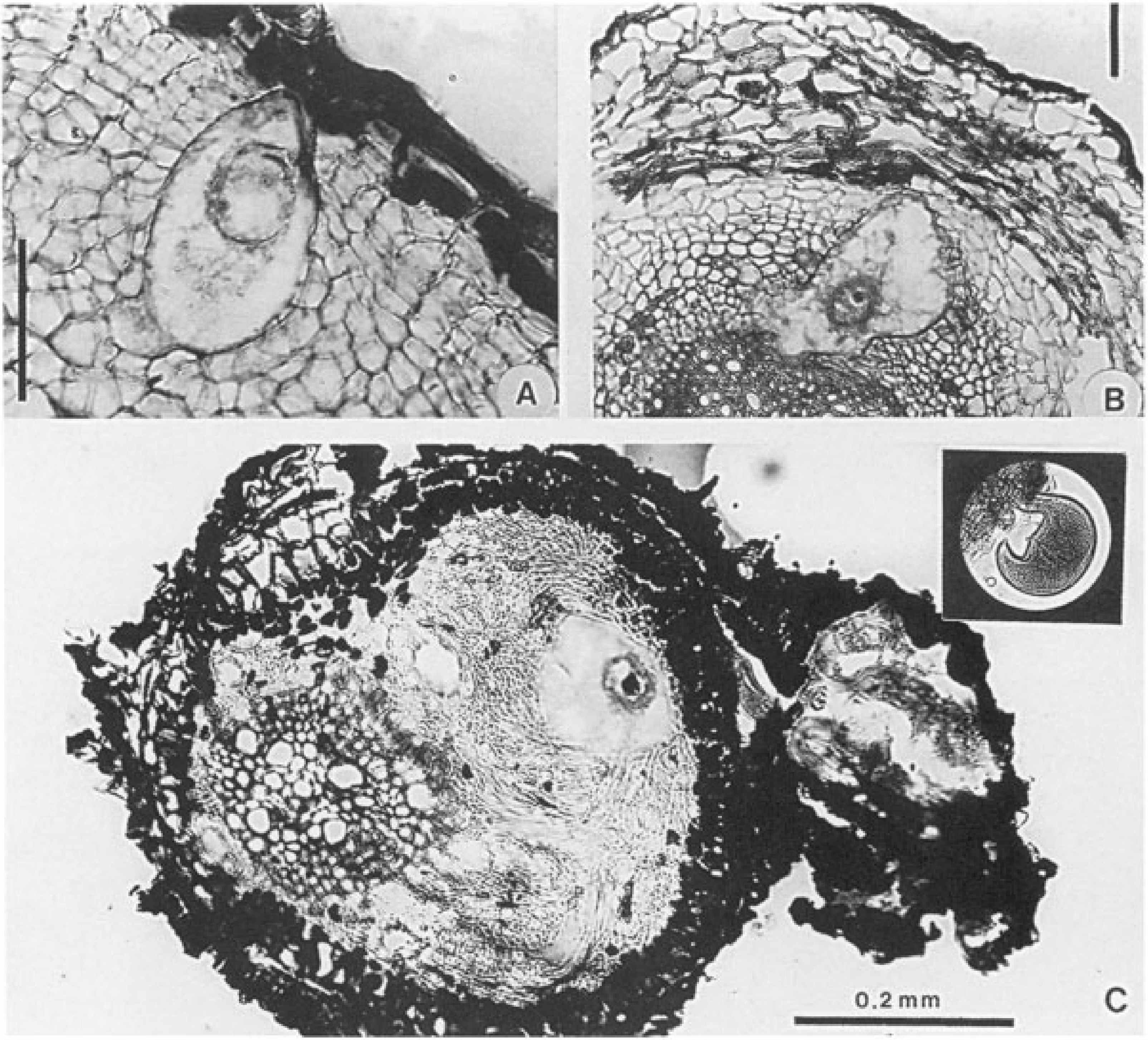

Fig. 7. Trophic sites induced by *Rotylenchulus macrodoratus.* Nematode-infected cross sections of *Ficus carica* (A), *Olea europaea* (B), and *Pistacia vera* (C) roots showing an uninucleate giant cell with hypertrophied nucleus and prominent nucleolus in the stele. Scale bars in A and B = 50 μm. (After Inserra and Vovlas, 1980; Vovlas, 1983).

including *Brassica oleracea* var. *botrytis* (Khan and Khan, 1985), *Carica papaya* (Sivakumar and Seshadri, 1972), *Coffea arabica* (Vovlas and Lamberti, 1990), *Cucumis melo* var. *cantalupensis* (Heald, 1975; Heald *et al.*, 1988), *Cucumis sativus* (Birchfield, 1972), *G. max* (Cohn, 1976; Farahat and Kheir, 1983; Jones and Dropkin, 1975; Meredith *et al.*, 1983; Rebois *et al.*, 1975), *Gossypium hirsutum* (Birchfield, 1962; Cohn, 1973, Cohn, 1976; Rebois, 1980), *Helianthus annuus* (Robinson and Orr, 1980), *I. batatas* (Birchfield, 1972), *Lycopersicon esculentum* (Cohn, 1973; Khan *et al.*, 1985; Sivakumar and Seshadri, 1972), *Mentha* sp. (Cohn, 1973, 1976), *Musa acuminata* (Fig. 8A-C) (Vovlas and Ekanayake, 1985), *Nicotiana tabacum* (Patel, 1986; Patel *et al.*, 1988), *Passiflora edulis* f. sp. *flavicarpa* (Suárez *et al.*, 1993), *Phaseolus vulgaris* (Birchfield, 1972; Farahat and Kheir, 1983), *Pisum sativum* (Farahat and Kheir, 1983), *Ricinus communis* (Sivakumar and Seshadri, 1972), *S. officinarum* (Birchfield, 1972), *Trifolium alexandrinum* (Massoud and Gharob, 1988), *Vigna unguiculata* (Birchfield, 1972; Razak and Evans, 1976; Taha and Kassab, 1979), *V. vinifera* (Taha and Sultan, 1979), *Washingtonia robusta* (Inserra *et al.*, 1994), and *Z. mays* (Birchfield, 1972).

The host responses induced by different *Rotylenchulus* species are not necessarily identical on the same host, and histological responses to a single species can differ somewhat among plant species. However, some generalizations can be made, realizing that exceptions do occur. During root invasion, the anterior portion of the body of the vermiform female penetrates the epidermis and cortical parenchyma of the root and usually stops to feed permanently on a single endodermal cell (Fig. 6A). This results in the formation of a trophic site. Except for *R. macrodoratus*, the trophic site usually consists of a stelar syncytium, which originates from an endodermal cell and enlarges by incorporating a curved sheet of cells in the pericycle, vascular parenchyma, and sometimes phloem, through partial dissolution of common cell walls (Fig. 6B). Syncytial cells have densely staining granular cytoplasm and enlarged nuclei, and are slightly hypertrophied

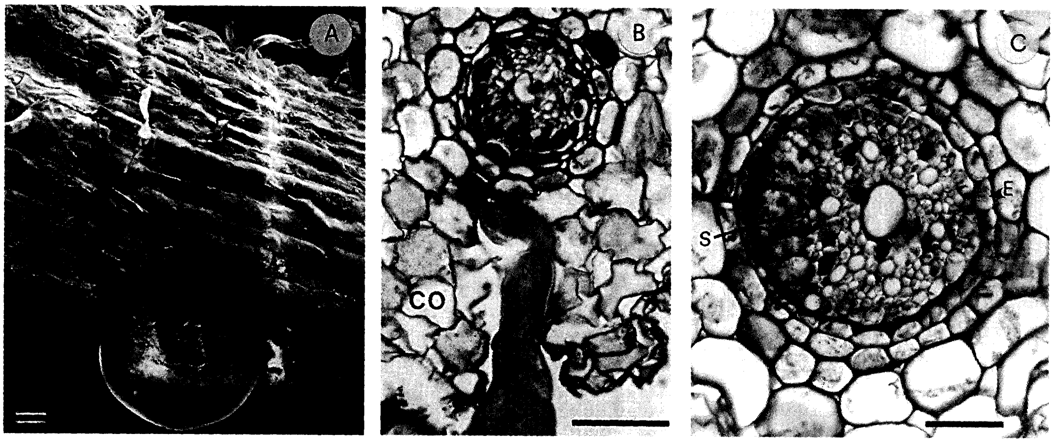

Fig. 8. Anatomical alterations induced by *Rotylenchulus reniformis* on *Musa acuminata* roots. A) Root infected by a swollen female. B) Female (N) partially penetrated into the cortical parenchyma (CO). C) Syncytium (S) induced by nematode feeding activity and expanded from the endodermis (E) into the pericycle and vascular parenchyma. Scale bars for all figures = 50 μm. (After Vovlas and Ekanayake, 1985).

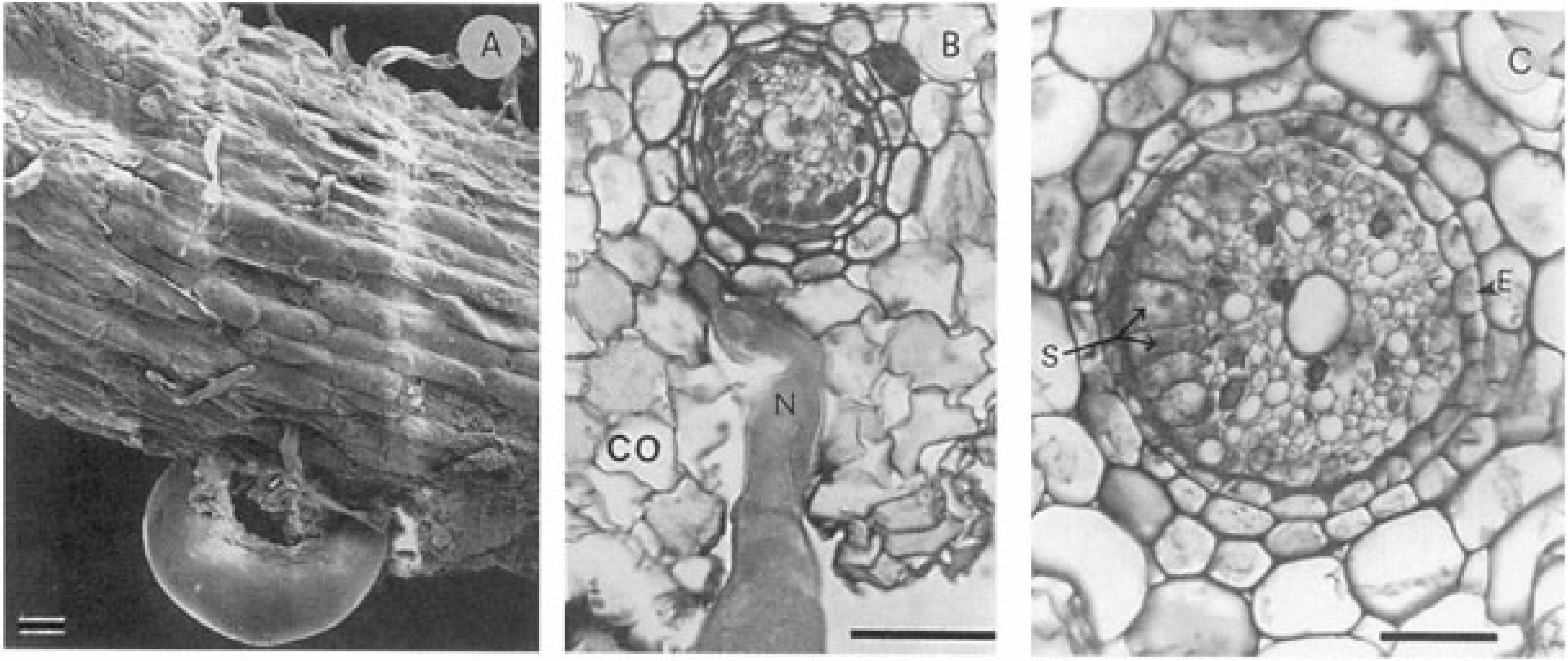

Fig. 8. Anatomical alterations induced by *Rotylenchulus reniformis* on *Musa acuminata* roots. A) Root infected by a swollen female. B) Female (N) partially penetrated into the cortical parenchyma (CO). C) Syncytium (S) induced by nematode feeding activity and expanded from the endodermis (E) into the pericycle and vascular parenchyma. Scale bars for all figures = 50 µm. (After Vovlas and Ekanayake, 1985).

(Rebois *et al.*, 1975; Vovlas and Inserra, 1982; Vovlas *et al.*, 1985) (Figs. 6B; 8B,C). In all seven hosts examined so far, the trophic site induced by *R. macrodoratus* consisted of an hypertrophied, uninucleate giant cell of endodermal origin (Cohn, 1976; Cohn and Mordechai, 1977; Inserra and Vovlas, 1980) (Fig. 7A-C). Specialized feeding sites typically do not differ appreciably among plant-parasitic nematodes within the same genus. *Rotylenchulus* appears to be an exception since *R. macrodoratus* induces a uninucleate giant cell, while other species (*R. borealis, R. macrosoma, R. parvus,* and *R. reniformis*) induce a syncytium in the stele of host roots (Fig. 9). In various concomitant infections of plant roots by *R. reniformis* and other sedentary nematodes, the characteristic plant response to each species occurred as if the other nematode species were absent (Heald *et al.*, 1988; Jones and Dropkin, 1975; Massoud and Ghorab, 1988; Patel *et al.*, 1988; Taha and Kassab, 1979; Vovlas and Ekanayake, 1985).

A temporal study of infection by *R. reniformis* on resistant and susceptible soybean with the transmission electron microscope revealed that syncytial development in susceptible plants went through two phases: 1) an initial phase involving partial cell wall lysis and separation, and 2) an anabolic phase characterized by organelle proliferation and secondary wall deposits (Rebois *et al.*, 1975). In resistant plants, the initial phase was accelerated, resulting in

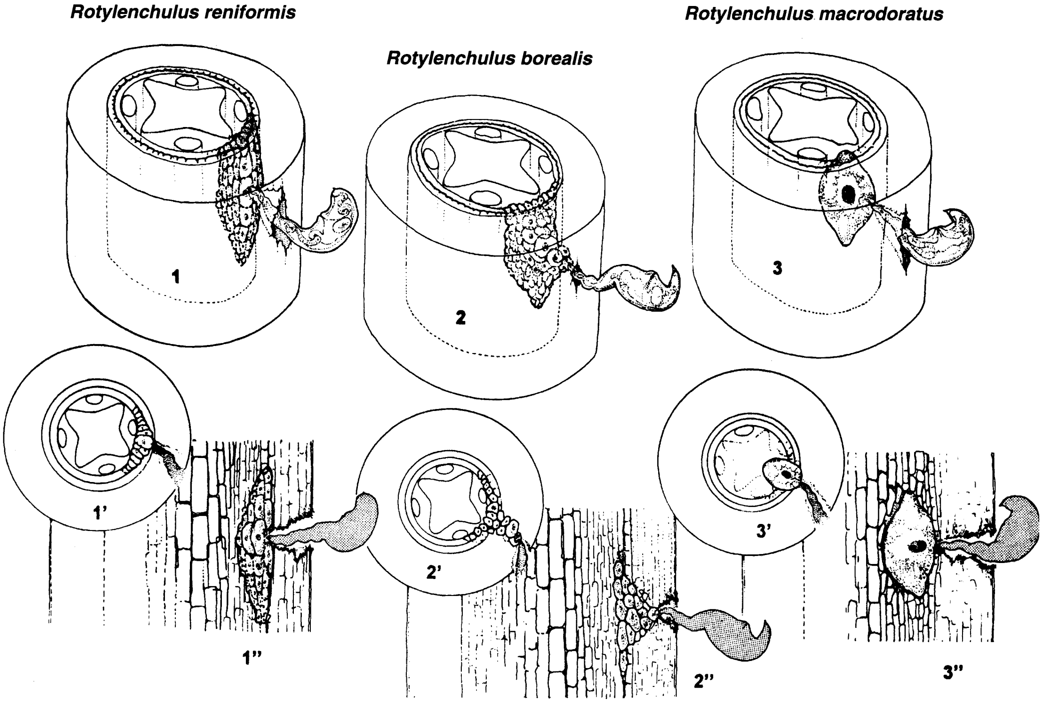

Fig. 9. Schematic representation in tridimensional (1-3), transversal (1'-3'), and longitudinal (1"-3") view of trophic sites induced by reniform nematode species. Note the uninucleate giant cell (3, 3', and 3") induced by *Rotylenchulus macrodoratus* compared to the syncytium, which is the most common host response caused by *Rotylenchulus* species including *R. reniformis* (1, 1', and 1") and *R. borealis* (2, 2', and 2").

cell lysis and thus failure to enter the anabolic phase. A similar response has been reported for the old world cotton species, *Gossypium arboreum* (Carter, 1981b).

ROTYLENCHULUS RENIFORMIS

Rotylenchulus reniformis (Figs. 10, 11) is the *Rotylenchulus* species of greatest economic importance. Excellent reviews on its biology, systematics, distribution, economic impact, and management are given by Varaprasad (1986) and Gaur and Perry (1991b). We will briefly discuss and update the geographical distribution and economic impact of *R. reniformis* but will focus on host range, immune species, sources of resistance in crop plants, and opportunities for crop rotation.

Geographical distribution: Rotylenchulus reniformis has been found in association

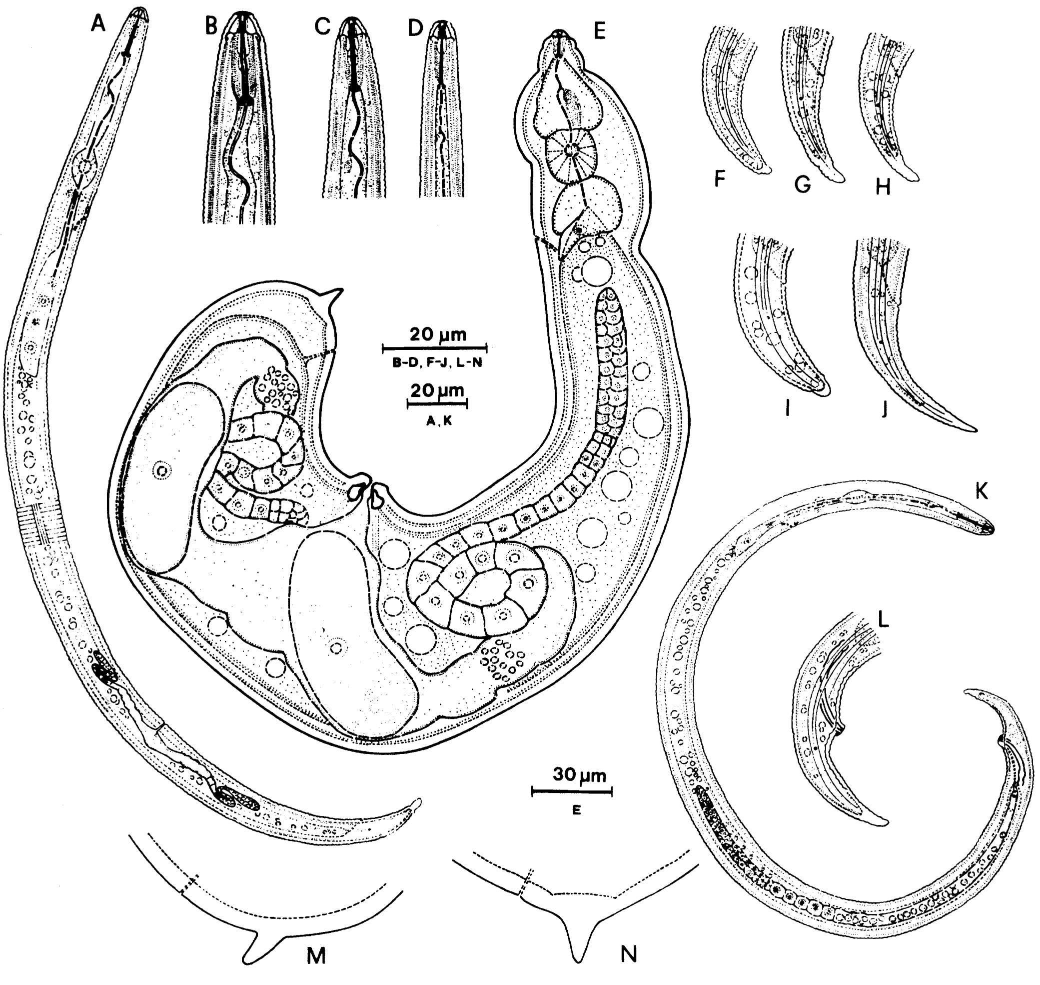

Fig. 10. *Rotylenchulus reniformis* life stages. A) Immature female. B) Anterior portion of the body of immature female. C) Anterior portion of the body of juvenile. D) Anterior portion of the body of male. E) Mature female. F-I) Tail of immature female. J) Tail of juvenile. K) Male. L) Tail of male. M, N) Tail of mature female. (After Dasgupta *et al.*, 1968, modified).

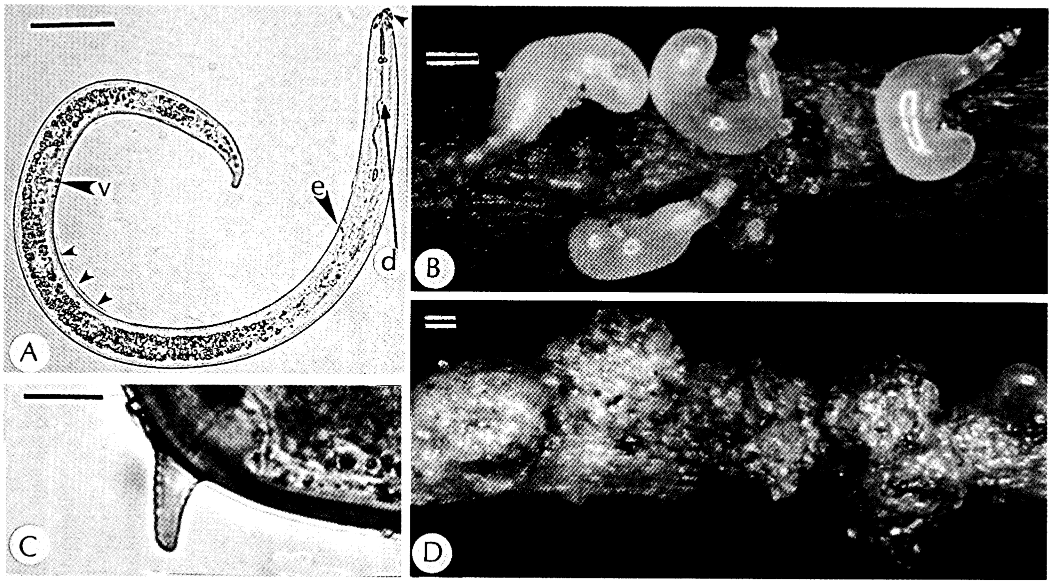

Fig. 11. Selected life stages of *Rotylenchulus reniformis.* A) Immature female enclosed in the cuticles (indicated by small arrow heads) of juvenile stages. d = dorsal esophageal gland orifice; e = excretory pore; v = vulva. B) *Gossypium* sp. feeder root infected by swollen females artificially detached from the root tissues. C) Posterior portion of the body of a swollen female showing the characteristic spike-like terminus. D) Egg masses attached to a cotton feeder root. Scale bars = 32 µm in A, 110 µm in B and D, and 8 µm in C. (Photos B and D courtesy of C. Overstreet).

with hundreds of crop and native plants in tropical, subtropical, and warm temperate regions in thousands of localities in South America, Central America, North America, the Caribbean Basin, Africa, southern Europe (Malta and Spain only), the Middle East, India, Southeast Asia, Australasia, the Indian Ocean, China, Japan, the Philippines, and the Pacific. Its wide distribution likely resulted from an exceptionally wide host range (Table 2) and an ability to survive extended periods in a dehydrated state (Birchfield and Martin, 1967; Gaur and Perry, 1991a; Heald and Inserra, 1988; Inserra and Dunn, 1992; Radewald and Takeshita, 1964; Rodriguez-Fuentes, 1980; Sehgal and Gaur, 1988, 1989; Tsai and Apt, 1979; Womersley and Ching, 1989). Anhydrobiotic *R. reniformis* are dispersed long distances in dust storms (Gaur, 1988).

Host range: Several extensive host lists and numerous new host records for *R. reniformis* have been published (Table 2). The reliability of original host records varies greatly, as do the criteria used to assign host status. Authors of host lists often have listed previous reports of *R. reniformis* from soil samples taken near a suspected host, separate from reports that confirmed reproduction by directly observing mature females and eggs, or that confirmed reproduction by monitoring population increases in pot experiments. Even so, in many cases the wording of a report is not clear enough to know precisely what was and was not observed. In other cases, *R. reniformis* was assumed to be the *Rotylenchulus* species present or the authors stated that the species was not determined.

Thorne (1961) predicted that hundreds of hosts for *R. reniformis* would be found. In our examination of the literature, we found reports of reproduction by *R. reniformis* on 314 of 364 plant species

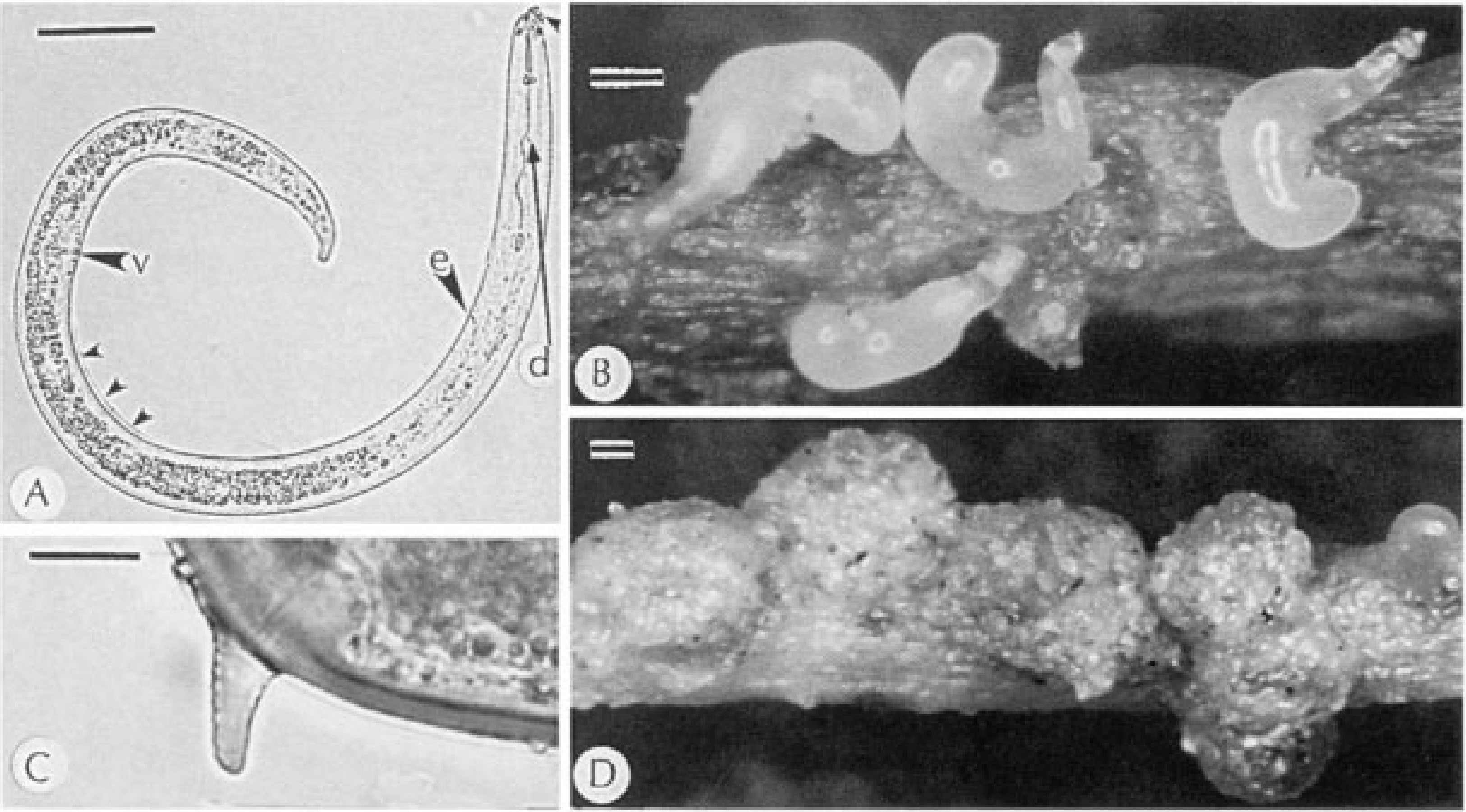

Fig. 11. Selected life stages of *Rotylenchulus reniformis.* A) Immature female enclosed in the cuticles (indicated by small arrow heads) of juvenile stages. d = dorsal esophageal gland orifice; e = excretory pore; v = vulva. B) *Gossypium* sp. feeder root infected by swollen females artificially detached from the root tissues. C) Posterior portion of the body of a swollen female showing the characteristic spike-like terminus. D) Egg masses attached to a cotton feeder root. Scale bars = 32 µm in A, 110 µm in B and D, and 8 µm in C. (Photos B and D courtesy of C. Overstreet).

Table 2. Reported hosts and nonhosts for *Rotylenchulus reniformis* according to numeric literature references as footnoted.

	Abelmoschus esculentus (L.) Moench	12, 44, 49, 56, 73, 104
	Abutilon theophrasti Medic.	104
	Acalypha arvensis Poepp. & Endl	76
	Acoelorrhaphe wrightii (Griseb. & H. Wendl.) H. Wendl. ex Becc.	41
	Adansonia digitata L.	96
	Aeschynomene americana L.	38, 76
	Aeschynomene virginica (L.) BSP	14
	Ageratum conyzoides L.	51, 56, 76
H/NH	*Allium cepa* L.	12, 15, 47, 87
H/NH	*Allium sativum* L.	45, 87, 92
	Aloe vera (L.) Brum. f.	R. N. Inserra, 1997′
	Amaranthus dubius Mart. ex Thell.	76
	Amaranthus spinosus L.	38, 51, 76
H/NH	*Amaranthus viridis* L.	35, 51, 92
	Ananas comosus (= *sativus*) (L.) Merril	50, 56, 82, 83
NH	*Anethum graveolens* L.	45, 47
	Annona squamosa L.	46
	Anoda cristata (L.) Schlechtend	104
	Arachis hypogaea L.	12
NH	Archontophoenix alexandre	41
NH	*Areca catechu* L.	50
	Argemone mexicana L.	92
	Argyreia nervosa (Burm. f.) Bojer	56
	Artemisia vulgaris L.	76
	Articum lappa L.	70
	Artocarpus altilis (Parkins.) Fosb.	21
	Artocarpus heterophyllus Lam.	46
	Asphodelus fistulosus (= *tenufilolius*) L.	51
NH	*Avena sativa* L.	12
	Averrhoa carambola L.	46
	Begonia semperflorens Link & Otto	56
	Benincasa hispida (Thumb.) Cogn.	44
	Beta vulgaris L.	12, 56
	Bidens pilosa L.	38, 76, 92
NH	*Bismarckia nobilis* Hildebr. & H. Awend.	41
	Bixa orellana L.	56
	Blumea hieracifolia DC.	51
	Brachiaria mutica (Fosk.) Stapf	86
	Brassica napus L.	92
H/NH	*Brassica nigra* (L.) W. D. J. Koch	12, 44
	Brassica oleracea L. *acephala* group	56
	Brassica oleracea L. *botrytis* group	56
	Brassica oleracea L. *capitata* group	47, 56
H/NH	*Brassica rapa* L.	12, 47, 56
	Brassica rapa L. *pekinensis* group	56
	Buddleia asiatica Lour.	56
	Caesalpinia (= *Poinciana*) *pulcherrima* (L.) SW.	73, 74
	Cajanus acutifolius (F. Muell.) Maesen [= *Atylosia acutifolia* (F. Muell. ex Benth) Reynolds & Peley]	84
	Cajanus albicans (W. & A.) Maesen (= *Cantharosperma albicans* Wight & Am.)	84
	Cajanus cajan (L.) Millsp.	56, 87
	Cajanus cajanifolius (Haines) Maesen (= *Atylosia cajanifolia* Haines)	84
	Cajanus goensis Dalz. ex Hook. (= *Atylosia barbata* Barker ex Hook.)	84
	Cajanus grandifolius (Benth. ex Baker) Maesen (=*Atylosia grandifolia* Benth. ex Hook.)	84

Table 2. (Continued) Reported hosts and nonhosts for *Rotylenchulus reniformis* according to numeric literature references as footnoted.

	Cajanus lanceolatus (W. Fitzg.) Maesen (= *Atylosia lanceolata* W. Fitzg.)	84
	Cajanus lineatus (W. & A.) Maesen (= *Atylosia Mollis* Benth. ex Mig.)	84
	Cajanus platycarpus (Benth.) Maesen (*Atylosia* platycarpa Benth.)	84
	Cajanus reticulatus F. Muell. (*Atylosia reticulata* Benth. ex Hook.)	84
	Cajanus scarabaeoides (L.) Thomas	84
	Cajanus sericeus (Benth. ex Baker) Maesen (= *Atylosia sericea* Benth. ex Hook.)	84
	Cajanus volubilis Blanco (= *Atylosia Mollis* Benth. ex Mig.)	84
	Calendula officinalis L.	56
	Callistephus chinensis (L.) Nees.	56
	Camellia sinensis (L.) Kuntze	27, 50
H/NH	*Canavalia ensiformis* (L.) DC.	73, 74, 92
H/NH	*Capsicum annuum* L.	12, 81, 88
H/NH	*Capsicum annuum* var. *frutescens* (L.) Kuntze	12, 47, 73, 74
	Carica cauliflora Jacq.	72
	Carica gracilis Solms	85
	Carica papaya L.	56
	Carissa carandus L.	46
NH	*Carpenteria acuminata* (author uncertain)	41
NH	*Caryota mitis* Lour.	41
	Centella asiatica (L.) Urban.	51, 56
	Centrosema pubescens Benth.	6
NH	*Chamadorea cataractarum* Mart.	41
NH	*Chamaerops humilis* L.	41
	Chamaesyce nutans (Lag.) Small	6
	Chamaesyce ophtalmica (Pers.) Burch	53
	Chamaesyce (= *Euphorbia) hirta* (L.) Millsp.	56, 59, 76
	Chamaesyce (= *Euphorbia) hypercifolia* (L.) Millsp.	56
	Chamaesyce (= *Euphorbia) thymifolia* (L.) Millsp.	51
NH	*Chenopodium album* L.	51
	Chenopodium murale L.	51
NH	*Chloris gayana* Kunth	18
	Chlorophytum comosum (Thumb.) Jacques	90
	Cicer arietinum L.	60
	Cichorium intybus L.	46
	Cienfuegosia drummondii (Gray) Lewt.	104
NH	*Cinnamomum verum* (= *zeylandium)* J. Presl.	50
	Citrullus lanatus (Thunb.) Matsum. & Nakai	12
NH	*Citrus aurantifolia* (Christm.) Swingle	50
NH	*Citrus jambhiri* Lushington	50
H/NH	*Citrus limon* (L.) Burm. f.	37, 73, 74
NH	*Citrus limonia* Osbeck	28
NH	*Citrus reticulata* Blanco	50
	Citrus sinensis (L.) Osbeck	6
	Cleome aculeata L.	76
H/NH	*Cleome rutidosperma* (= *ciliata*) DC.	76, 86
	Cleome viscosa L.	76
	Coccoloba uvifera L.	56
NH	*Cocothrinax* sp.	41
	Coffea arabica L.	7, 58, 92, 99, 101
H/NH	*Coffea canephora* (= *robusta*) Pierre & Froehner	58, 73, 74, 99
	Coffea excelsa (author uncertain)	99

Table 2. (Continued) Reported hosts and nonhosts for *Rotylenchulus reniformis* according to numeric literature references as footnoted.

	Colocasia esculenta (L.) Schott	64
	Commelina diffusa Burm. f.	38, 76
	Commelina erecta (L.) Chev. (= *elegans* HBK.)	86
	Convolvulus arvensis L.	51
	Conyza bonariensis (L.) Crong. [= *Erigeron albidus* (Willd.) Gray]	56
	Cordyline fructicosa (L.) Chev. [= *terminalis* (L.) Kunth]	5
	Coronopus didymus (L.) Sm.	51
NH	*Crotalaria breviflora* DC.	89
H/NH	*Crotalaria juncea* L.	18, 73, 89
NH	*Crotalaria lanceolata* E. Mey.	89
H/NH	*Crotalaria pallida* Aiton var. *obvata* (G. Don) Polhill (= *C. mucronata* Desv.)	73, 89
	Crotalaria spectabilis Roth	56, 89
NH	*Crotalaria virgulata* Klotsch. ssp. *grantiana* (Harvey) Polhill	89
	Cucumis melo L.	12, 34, 44
	Cucumis sativus L.	12, 44, 47, 56
	Cucurbita maxima Duchesne ex Lam.	6
	Cucurbita moshata (Duchesne) Poir.	44, 92
	Cucurbita pepo L.	12, 56
NH	*Cycas revoluta* Thumb	41
	Cynara scolymus L.	56
H/NH	*Cynodon dactylon* (L.) Pers.	12, 51, 87
	Cyperus esculentus L.	65
H/NH	*Cyperus* (= *Torulinium*) *odoratus* L.	76, 86
H/NH	*Cyperus rotundus* L.	51, 86
NH	*Dactyloctenium aegyptiacum Willd.*	51
H/NH	*Daucus carota* L.	12, 45, 56, 73, 74
	Desmodium tortuosum (Sw.) DC.	19
	Dichanthium annulatum (Forsk.) Stapf	46
	Digitaria eriantha Steud. (= decumbens Stent.)	18
	Digitaria sanguinalis (L.) Scop.	14
	Dioscorea polygonoides Humb. & Bonpl. ex Willd.	92
	Dioscorea rotundata Poir.	2
	Echeveria sp.	56
H/NH	*Echinochloa crus-galli* (L.) Beauv.	12, 14
	Elettaria cardamomum (L.) Maton	50
	Eleusine indica (L.) Gaertn.	67, 76
	Emblica officinalis (*Phyllanthus emblica* L.)	46
	Emilia coccinea (Sims) G. Don	86
	Emilia fosberghii D. H. Nicolson	76
	Emilia sonchifolia (L.) DC.	56
	Emilia sonchifolia (L.) var. *javanica* (Burm.f.) Matttf.	53
NH	*Eragrostis pilosa* (L.) Beauv.	51
	Erechtites valerianaefolia (Spreng.) DC.	56
	Euphorbia heterophylla (L.)	38, 59, 76
	Euphorbia milii Des Moulins	26
	Euphorbia pulcherrima Willd. ex Klotzsch	56
	Ficus carica L.	46
	Ficus elastica Roxb. ex Hornem.	90
	Fimbristylis miliacea (L.) Vahl	86
	Flemingia macrophylla Blume	84
	Flemingia stricta Wall.	84
	Flemingia strobilifera (L.) Ait. & Ait.f.	84
	Foeniculum vulgare Mill	44
	Galinsoga quadriradiata (= *ciliata*) Ruiz & Pavon	38, 59, 76

Table 2. (Continued) Reported hosts and nonhosts for *Rotylenchulus reniformis* according to numeric literature references as footnoted.

	Colocasia esculenta (L.) Schott	64
	Commelina diffusa Burm. f.	38, 76
	Commelina erecta (L.) Chev. (= *elegans* HBK.)	86
	Convolvulus arvensis L.	51
	Conyza bonariensis (L.) Crong. [= *Erigeron albidus* (Willd.) Gray]	56
	Cordyline fructicosa (L.) Chev. [= *terminalis* (L.) Kunth]	5
	Coronopus didymus (L.) Sm.	51
NH	*Crotalaria breviflora* DC.	89
H/NH	*Crotalaria juncea* L.	18, 73, 89
NH	*Crotalaria lanceolata* E. Mey.	89
H/NH	*Crotalaria pallida* Aiton var. *obvata* (G. Don) Polhill (= *C. mucronata* Desv.)	73, 89
	Crotalaria spectabilis Roth	56, 89
NH	*Crotalaria virgulata* Klotsch. ssp. *grantiana* (Harvey) Polhill	89
	Cucumis melo L.	12, 34, 44
	Cucumis sativus L.	12, 44, 47, 56
	Cucurbita maxima Duchesne ex Lam.	6
	Cucurbita moshata (Duchesne) Poir.	44, 92
	Cucurbita pepo L.	12, 56
NH	*Cycas revoluta* Thumb	41
	Cynara scolymus L.	56
H/NH	*Cynodon dactylon* (L.) Pers.	12, 51, 87
	Cyperus esculentus L.	65
H/NH	*Cyperus* (= *Torulinium*) *odoratus* L.	76, 86
H/NH	*Cyperus rotundus* L.	51, 86
NH	*Dactyloctenium aegyptiacum Willd.*	51
H/NH	*Daucus carota* L.	12, 45, 56, 73, 74
	Desmodium tortuosum (Sw.) DC.	19
	Dichanthium annulatum (Forsk.) Stapf	46
	Digitaria eriantha Steud. (= decumbens Stent.)	18
	Digitaria sanguinalis (L.) Scop.	14
	Dioscorea polygonoides Humb. & Bonpl. ex Willd.	92
	Dioscorea rotundata Poir.	2
	Echeveria sp.	56
H/NH	*Echinochloa crus-galli* (L.) Beauv.	12, 14
	Elettaria cardamomum (L.) Maton	50
	Eleusine indica (L.) Gaertn.	67, 76
	Emblica officinalis (*Phyllanthus emblica* L.)	46
	Emilia coccinea (Sims) G. Don	86
	Emilia fosberghii D. H. Nicolson	76
	Emilia sonchifolia (L.) DC.	56
	Emilia sonchifolia (L.) var. *javanica* (Burm.f.) Matttf.	53
NH	*Eragrostis pilosa* (L.) Beauv.	51
	Erechtites valerianaefolia (Spreng.) DC.	56
	Euphorbia heterophylla (L.)	38, 59, 76
	Euphorbia milii Des Moulins	26
	Euphorbia pulcherrima Willd. ex Klotzsch	56
	Ficus carica L.	46
	Ficus elastica Roxb. ex Hornem.	90
	Fimbristylis miliacea (L.) Vahl	86
	Flemingia macrophylla Blume	84
	Flemingia stricta Wall.	84
	Flemingia strobilifera (L.) Ait. & Ait.f.	84
	Foeniculum vulgare Mill	44
	Galinsoga quadriradiata (= *ciliata*) Ruiz & Pavon	38, 59, 76

Table 2. (Continued) Reported hosts and nonhosts for *Rotylenchulus reniformis* according to numeric literature references as footnoted.

	Lepidium virginicum L.	92		*Nerium oleander* L.	5, 54
	Leucas urticaefolia R. Br.	51		*Nicotiana tabacum* L.	7, 57, 68, 73, 74
	Litchi chinensis Sonn.	46		*Nolina* (= *Beaucarnea*) *recurvata* (Lem.) Hemsl.	90
	Luffa acutangula (L.) Roxb.	46		*Olea europaea* L.	3
	Luffa cylindrica (L.) M. Roem.	44	H/NH	*Oryza sativa* L.	12, 46
H/NH	*Lycopersicon esculentum* Mill.	10, 47, 56, 73, 74, 77, 87		*Parietaria floridana* Nutt.	Pers. comm., R. N. Inserra
H/NH	*Lycopersicon pimpinellifolium* (Jusl.) Mill.	10, 77			
	Macroptilium (= *Phaseolus*) *lathyroides* (L.) Urban	56		*Parthenium crispum* (Mill.) Airy-Shaw	92
				Parthenium hysterophorus L.	38, 59, 65, 76
	Malpighia glabra L.	25		*Paspalum conjugatum* Berg.	86
	Malvaviscus arboreus Cav.	104	NH	*Paspalum dilatatum* Poir.	12
	Mangifera indica L.	9, 66, 100		*Paspalum fasciculatum* Willd. ex Fluegge	86
	Manihot esculenta Crantz	6, 73, 74		*Passiflora edulis* Sims.	48
	Mentha sp.	22		*Passiflora seemanni* Griseb.	56
	Merremia (= *Ipomea*) *tuberosa* (L.) Rendle	56		*Persea americana* (= *gratissima*) Mill.	57, 74
H/NH	*Mimosa pudica* L.	6, 76		*Phaseolus lunatus* (= *limensis*) L.	12, 56
	Modiola caroliniana (= *multida*) (L.) G. Don	13, 104		*Phaseolus semierectus* L.	57
NH	*Mollugo hirta* (author uncertain)	51		*Phaseolus vulgaris* L.	1, 12, 44, 56, 63, 73, 74
	Momordica balsamina L.	92		*Phenax sonneratii* Wedd.	76
	Momordica charantia L.	44		*Philodendron bipinnatifidium* (= *selloum*) Endl.	90
NH	*Mucuna* (= *Styzolobium*) *pruriens* (= *derringiana*) (L.) DC. var. *utilis* (Wallich ex Wight) Baker ex Burck	74		*Phlox drummondii* Hook.	56
			NH	*Phoenix roebelenii* O'Brien	41
				Phyllanthus amarus Schumacher	76
	Murraya paniculata (= *exotica*) (L.) Jack	56		*Phyllanthus carolinensis* Walter	38, 65
	Musa acuminata Colla	75		*Phyllanthus niruri* L.	51
	Musa martinii Hort. ex Carriere	92	NH	*Phyllanthus urinaria* L.	76
	Musa paradisiaca L.	6		*Physalis angulata* L.	76
NH	*Myristica fragans* Houtt.	50		*Pilea microphylla* (L.) Liebm.	38
NH	*Neodypsis decaryi* Jumelle	41		*Piper betle* L.	1
NH	*Neodypsis lastelliana* Baill.	41		*Piper nigrum* L.	50

Table 2. (Continued) Reported hosts and nonhosts for *Rotylenchulus reniformis* according to numeric literature references as footnoted.

	Pisum sativum L.	56
	Polyscias guilfoylei (Bull.) L. H. Bailey	56
	Portulaca oleracea L.	38, 56, 76
	Prosopis glandulosa (= *chilensis*) Torr.	56
	Prunus armeniaca L.	46
	Prunus insititia (= *bokhariensis*) Poir.	46
	Prunus persica (L.) Batsch.	46
	Psophocarpus tetragonolobus (L.) DC.	4
NH	*Ptychosperma elegans* (R.Br.) Blume	41
	Pueraria montana (= *hirsuta* = *thumbergiana*) (Lour.) mer. var. *lobata* (Willd.)	57, 93
	Pueraria phaseoloides (Roxb.) Benth.	92
	Pyrus malus L.	46
NH	*Quercus calliprinos* Webb	22
	Radermachera sinica (Hance) Hemsl.	90
	Raphanus sativus L.	56
NH	*Ravenea rivularis* Jumelle & Perrier	41
NH	*Rhapis excelsa* L.F.	41
	Rhynchosia aurea DC.	84
	Rhynchosia bracteata Benth. ex Baker	84
	Rhynchosia cana DC.	84
	Rhynchosia densiflora (Roth) DC.	84
	Rhynchosia minima (L.) DC.	84
	Rhynchosia rothii (author uncertain)	84
	Rhynchosia rufescens DC.	84
	Rhynchosia suaveolens DC.	84
	Rhynchosia sublobata (Schum.) Meikle	84
	Richardia scabra L.	56
	Ricinus communis L.	10, 30, 44, 47, 92
	Rottboellia cochinchinensis (= *exaltata*) (Lour.) Clayton	76,92
NH	*Sabal palmetto* (Walt.) Lodd. ex Schult. & Shult.f.	41
H/NH	*Saccharum officinarum* L.	7, 11, 12, 67
	Sansevieria trifasciata Prain.	90
	Schefflera (= *Brassaia*) *actiniphylla* (Endl.) Harms	90
	Schefflera (= *Brassaia*) *arboricola* (Hayata) Merr.	90
	Schinus terebinthifolius Raddi	56, 91
	Senna (= *Cassia*) *torta* (L.) Roxb.	19
	Sesamum indicum L.	92
	Sesbania exaltata (raf.) V.L. Cory	14
	Setaria barbata (Lam.) Kunth	76
	Setaria glauca (L.) Beauv. [= *Pennisetum typhoides* (Burm.) Stapf & C. E. Hubb]	45
H/NH	*Sida rhombifolia* L.	92, 104
	Sida spinosa L.	14
	Solanum melongena L.	47, 56, 73, 74
	Solanum nigrum L.	56
	Solanum tuberosum L.	56
	Solenostemon (= *Coleus*) *scutellaroides* (L.) Codd.	56
	Sonchus oleraceus L.	65
H/NH	*Sorghum bicolor* (= *Andropogon sorghum*) (L.) Moench	6, 12, 56, 65
	Sorghum halepense (L.) Pers.	14
NH	*Spermacoce assurgens* Ruiz & Pavon	76
NH	*Spermacoce confusa* Rendle	76

Table 2. (Continued) Reported hosts and nonhosts for *Rotylenchulus reniformis* according to numeric literature references as footnoted.

NH	*Spermacoce latifolia* Pohl ex DC.	76	*Urena lobata* L.	104
H/NH	*Spinacia oleracea* L.	12, 44, 47	*Vernonia cinerea* (L.) Less.	56, 76, 92
	Stachys arvensis L.	56	*Vicia faba* L.	98
NH	*Stachytarpheta jamaicensis* (L.) Vahl	76	*Vicia villosa* Roth	12, 57
NH	*Syagrus romanzoffiana* (Cham.) Glassman	41	*Vigna aconitifolia* (Jacq.) Marechal	69, 73, 74
	Synedrella nodiflora (L.) Gaertner	73	*Vigna radiata* (L.) R. Wilczek (= *Phaseolus aureus* Roxb.)	1, 17
	Syzygium (= *Eugenia*) *malaccense* (L.) Merr. & L. M. Perry	56	*Vigna unguiculata* (L.) Walp.	8, 29, 34, 40, 41, 42, 43, 47, 56, 73, 94
	Tagetes erecta L.	12, 56		
	Tagetes patula L.	18, 56	*Vigna mungo* (L.) Hepper	1, 46
	Theobroma cacao L.	50	*Vitis vinifera* L.	95
NH	*Thrinax morrisii* H. Wendl	41	*Waltheria indica* L.	38
	Trachycarpus fortunei (Hook.) H. Wendl.	39, 41	*Washingtonia robusta* H. Wendl.	41
NH	*Trianthema portulacastrum* L.	51	*Wodyetia bifurcata* A. K. Irvine	39, 41
	Tribulus terrestris L.	51	*Xanthium* sp.	19
	Trichosanthes dioica Roxb.	71	*Xanthosoma caracu* Koch & Bouche'	64
	Trifolium alexandrinum L.	62	*Xanthosoma nigrum* (= *violaceum*) [(Vell.) Conc.] Mansf.	64
	Trifolium incarnatum L.	12		
	Trifolium pratense L.	12	*Xanthosoma sagittifolium* (= *atrovirens*) (L.) Schott	64, 92
	Trifolium repens L.	12		
	Trigonella foenum-graecum L.	46	*Youngia* (= *Crepis*) *japonica* (L.) DC.	38, 56
	Triticum aestivum L.	47	*Zea mays* L.	12, 36, 56, 65, 87, 103
			Zinnia elegans Jacq.	56

Table 2. (Continued) Reported hosts and nonhosts for *Rotylenchulus reniformis* according to numeric literature references as footnoted.

References to hosts reported for Rotylenchulus reniformis.

1. Acharya and Padhi, 1987
2. Acosta and Ayala, 1975
3. Al-Sayed and Abdel-Hameed, 1991
4. Anonymous, 1978
5. Artero *et al.*, 1977
6. Ayala and Ramirez, 1964
7. Ayala, 1962
8. Badra and Ismail, 1981
9. Badra and Khattab, 1982
10. Balasubramanian and Ramakrishnan, 1983
11. Birchfield, 1972
12. Birchfield and Brister, 1962
13. Birchfield and Brister, 1963
14. Carter *et al.*, 1995
15. Carter, 1981a
16. Carter, 1981b
17. Castillo *et al.*, 1977
18. Caswell *et al.*, 1991
19. Christie, 1959
20. Clark and Wright, 1983
21. Coates-Beckford and Pereira, 1992
22. Cohn, 1976
23. El-Sherif and Embabi, 1975
24. El-Sherif *et al.*, 1973
25. Ferraz *et al.*, 1989
26. Gao, 1993
27. Gnanapragasam *et al.*, 1987
28. Goulart and Monteiro, 1995
29. Gupta and Yadav, 1980
30. Haque and Mukhopadhyaya, 1980
31. Heald and Heilman, 1971
32. Heald and Inserra, 1988
33. Heald and Meridith, 1987
34. Heald, 1975
35. Heffes *et al.*, 1990
36. Heffes *et al.*, 1992
37. Inserra and Duncan, 1996
38. Inserra *et al.*, 1989
39. Inserra, 1994
40. Inserra *et al.*, 1995
41. Inserra *et al.*, 1994
42. Khan and Husain, 1988
43. Khan and Husain, 1989a,b
44. Khan and Khan, 1969
45. Khan and Khan, 1973
46. Khan, 1975
47. Khan, 1985
48. Kirby, 1978
49. Kumar and Sivakumar, 1981
50. Kumar *et al.*, 1971
51. Lal *et al.*, 1976
52. Lawrence and McLean, 1992
53. Lehman, 1990
54. Lehman, 1995
55. Lim and Castillo, 1979
56. Linford and Yap, 1940
57. Luc and de Guiran, 1960
58. Macedo, 1974
59. MacGowan, 1989
60. Mahapatra and Padhi, 1986
61. Martin and Birchfield, 1955
62. Massoud and Ghorab, 1988
63. McSorley, 1980
64. McSorley *et al.*, 1983
65. McSorley and Parrado, 1983
66. McSorley *et al.*, 1981
67. Mehta and Sundara, 1989
68. Melton and Powell, 1991
69. Mishra and Gaur, 1981
70. Nakasono, 1973
71. Nath *et al.*, 1976
72. Patel *et al.*, 1989
73. Peacock, 1956a
74. Peacock, 1956b
75. Perry *et al.*, 1962
76. Queneherve *et al.*, 1995
77. Rebois *et al.*, 1973
78. Rebois *et al.*, 1975
79. Rebois *et al.*, 1968
80. Robbins *et al.*, 1994a
81. Routaray *et al.*, 1988
82. Schenck, 1990
83. Schneider *et al.*, 1992
84. Sharma *et al.*, 1993
85. Singh and Farrell, 1972
86. Singh, 1974
87. Singh, 1975
88. Sivakumar *et al.*, 1979
89. Soares da Silva *et al.*, 1989
90. Starr, 1991
91. Steiner, 1949
92. Stoyanov, 1967
93. Stoyanov, 1971
94. Taha and Kassab, 1979
95. Taha and Sultan, 1979
96. Taylor *et al.*, 1978
97. Thomas and Clark, 1983
98. Timm, 1956
99. Valdez, 1968
100. Van Weerdt *et al.*, 1959
101. Vovlas and Lamberti, 1990
102. Walters and Barker, 1993
103. Windham and Lawrence, 1992
104. Yik and Birchfield, 1984

[1] Unpublished data from greenhouse experiment under controlled conditions.

examined (Table 2). Host classifications were largely consistent, and we found conflicting host reports for only 22 species (6% of all plant species examined). However, in the few cases where they occur, contradictory or incorrect host status assignments can be very important from a regulatory or crop rotation standpoint. This is particularly true for container-grown citrus trees (*Citrus* spp.) and ornamentals produced for export.

Gaur and Perry (1991b) noted that *R. reniformis* "preferred" dicotyledons. This may prove correct once enough plant species have been examined. About 76% of the 210,000 known species of angiosperms are dicots (Correll and Johnston, 1979) and almost the same percentage (78%) of the 364 plant species that have been examined as potential hosts for *R. reniformis* were dicots. In contrast, the overall incidence of nonhosts among monocots examined (33%) was much higher than among dicots (9%) as predicted by Gaur and Perry; however, most (18 of 26) of the monocot nonhosts that are known are palms (family Arecaceae/Palmae) and at present the incidence of known hosts for *R. reniformis* among other monocots (86%) is nearly as high as that reported for dicots (91%).

We found 77 plant families to contain reported hosts of *R. reniformis*. Many of these are tropical families in which only one or two species have been tested. The plant families which have received the most intense investigation as hosts of *R. reniformis* are Araceae, Arecaceae/Palmae, Asteraceae/Compositae, Euphorbiaceae, Fabaceae/Leguminosae, Malvaceae, Poaceae/Graminae, and Solanaceae. All contain crop or ornamental species of major economic importance. Araceae, Arecaceae/Palmae, and Poaceae/Graminae are monocot families; the others are dicots.

Immune and resistant plants: We found only 74 plant species to have been reported to be nonhosts and 22 of these have also been classified as hosts by some investigators (Table 3). Subspecific differences between the plants tested by different investigators undoubtedly have caused some differences in host status assignment. For example, turnip (*Brassica rapa*) was considered a nonhost by Birchfield and Brister (1962) whereas Chinese cabbage (*Brassica rapa* var. *pekinensis*) was classified as a host by Linford and Yap (1940). In some susceptible crops, certain cultivars or breeding lines are immune or highly resistant; a few breeding lines of tomato (*L. esculentum*) and accessions of *L. pimpinellifolium*, for example, are immune (Balasubramanian and Ramakrishnan, 1983; Rebois *et al.*, 1973). In some crop species, most cultivars are so highly resistant that populations almost invariably decrease in rotation studies and females with eggs can be found only with great difficulty or under special environmental circumstances. This situation could explain conflicting reports for onion (*Allium cepa*) (Birchfield and Brister, 1962; Carter, 1981a; Khan, 1985; Singh, 1975), bermudagrass (*Cynodon dactylon*) (Birchfield and Brister 1962; Lal *et al.*, 1976; Singh, 1975), rice (*Oryza sativa*) (Birchfield and Brister, 1962; Khan, 1975), pepper (*C. annuum*) (Birchfield and Brister, 1962; Routaray *et al.*, 1988; Sivakumar *et al.*, 1979), and some species of *Crotalaria* (Birchfield and Brister, 1962; Caswell *et al.*, 1991; Peacock, 1956b; Soares da Silva *et al.*, 1989). A histological study of onion showed that infrequent but normal trophic site development and nematode reproduction did occur on six cultivars when inoculated separately with three isolates of *R. reniformis* (Carter, 1981a). In one pot study on *Z. mays* (Windham and Lawrence, 1992), the resistance in 50 com-

Table 3. Contradictory host reports for *Rotylenchulus reniformis.*

Plant species	Host records	Nonhost records
Allium cepa L.	Singh, 1975; Carter, 1981a	Birchfield and Brister, 1962; Khan, 1985; Khan and Khan, 1973
Allium sativum L.	Stoyanov, 1967	Khan and Khan, 1973
Brassica nigra (L.) W. D. J. Koch	Khan and Khan, 1969	Birchfield and Brister, 1962
Brassica rapa L.	Linford and Yap, 1940	Birchfield and Brister, 1962; Khan, 1985
Canavalia ensiformis (L.) DC.	Stoyanov, 1967	Peacock, 1956b
Capsicum annuum L.	Routary *et al.*, 1988	Birchfield and Brister, 1962; Sivakumar *et al.*, 1979
Citrus limon (L.) Burm. f.	Peacock, 1956a, 1956b	Inserra and Duncan, 1996
Coffea canephora (= *robusta*) Pierre & Froehner	Valdez, 1968a	Macedo, 1974; Peacock, 1956b
Crotalaria juncea L.	Caswell *et al.*, 1991; Peacock, 1956b	Soares da Silva *et al.*, 1989
Crotalaria pallida Desv.	Peacock, 1956b	Soares da Silva *et al.*, 1989
Crotalaria spectabilis Roth	Linford and Yap, 1940	Soares da Silva *et al.*, 1989
Cynodon dactylon (L.) Pers.	Singh, 1975	Birchfield and Brister, 1962; Lal *et al.*, 1976
Cyperus rotundus L.	Singh, 1974	Lal *et al.*, 1976
Daucus carota L.	Peacock, 1956a; Linford and Yap, 1940	Khan and Khan, 1973
Echinochloa crus-galli (L.) Beauvois	Carter *et al.*, 1995	Birchfield and Brister, 1962
Oryza sativa L.	Khan, 1975	Birchfield and Brister, 1962
Saccharum officinarum L.	Mehta and Sundara, 1989	Ayala, 1962; Birchfield and Brister, 1962; Birchfield, 1972
Sida rhombifolia L.	Stoyanov, 1967	Yik and Birchfield, 1984
Sorghum bicolor (= *vulgare*) (L.) Moench	Peacock, 1956b	Birchfield and Brister, 1962
Spinacea oleracea L.	Khan and Khan, 1969	Birchfield and Brister, 1962

mercial hybrids was so high that populations remained below inoculum levels in all cases, with final populations for 46 hybrids less than 1% of the control [cotton (*G. hirsutum*) cv. Delta and Pineland 20]. Although no eggs whatsoever were found on 15 of the hybrids, the term "immune" was avoided and these plants were considered to be highly resistant.

An unsuspected potential cause of host status misassignment was discovered by Inserra and Duncan (1996) in pots containing both rough lemon (*Citrus limon*) and cowpea (*V. unguiculata*) plants; cowpea roots that supported normal nematode reproduction were entangled and easily confused with citrus roots, which supported no reproduction. Egg masses produced by females on cowpea roots were sometimes found adhering to rough lemon roots. In ornamental palm plantings and in citrus groves where weeds or cover crops occur, soil samples can easily contain roots from more than one plant species and in many cases, examinations of roots extracted from such samples could have led to host misidentification. Most common weeds are good hosts (Carter *et al.*, 1995; Edmunds, 1971; Gnanapragasam *et al.*, 1989; Inserra *et al.*, 1989; Quénehérvé *et al.*, 1995). The lack of reproduction of *R. reniformis* on citrus was confirmed by a host test conducted in Brazil using the citrus rootstock Rangpur lime (*Citrus limonia*), which was immune to nematode infection (Goulart and Monteiro, 1995).

Recent studies in Florida have clarified some ambiguities regarding the host status of ornamental palms (Arecaceae/Palmae). Of 20 palms tested by Inserra *et al.* (1991, 1994), only two were found to support any reproduction and in both cases (*Washingtonia robusta* and *Acoelorrhaphe wrightii)* final populations were only a fraction of the initial inoculum level. Previous associations of *R. reniformis* with certain palm species likely resulted from reproduction on weed hosts. Avocado (*Persea americana*) and mango (*Mangifera indica*) are listed as hosts for *R. reniformis* in the literature (Table 2); however, in a host test conducted in Florida, there was no evidence of nematode reproduction on the roots of these plants maintained for one year in soil infested with a nematode population from south Florida (Inserra, unpublished).

Host races of *R. reniformis* may account for some of the differences in host status observed by different investigators. Occurrence of a race incapable of reproducing on castor (*R. communis*) or Upland cotton in India, for example, is well established (Dasgupta and Seshadri, 1971a, 1971b). Other populations in India reproduce on castor and cotton. Differences in reproduction and damage caused by 17 populations from the United States on certain cultivars of cotton and soybean also have been observed (McGawley and Overstreet, 1995; pers. comm., E. C. McGawley, Louisiana State University). Sugarcane was originally considered immune to populations in Hawaii (Linford and Yap, 1940) and Louisiana (Birchfield and Brister, 1962), and reports of associations of high population densities of *R. reniformis* with sugarcane in Puerto Rico and the Dominican Republic led to speculation regarding occurrence of host races (Birchfield and Brister, 1962). Subsequent rigorous examinations for reproduction on sugarcane by Puerto Rican populations, however, revealed no reproduction (Ayala, 1962; Roman, 1964). Nonetheless, a population from India has been shown to reproduce on sugarcane under controlled conditions (Mehta and Sundara, 1989). The physiological differences required for a population of *R. reniformis* to reproduce on sugarcane may be simple, since sugarcane is a good host for *R. parvus* (Van den Berg and Spaull, 1981). There is additional evidence of differences between certain Indian populations and those from other parts of India and the world. Some cultivars of *Z. mays* (Srivastava and Sethi, 1986) and *C. annuum* (Routaray *et al.*, 1988), for example, are apparently good hosts for some Indian populations of *R. reniformis.* These plant species are considered highly resistant or immune to other populations of *R. reniformis.*

In Japan, three morphologically and reproductively different types of populations of *R. reniformis* occur, which are referred to as male numerous type (MNT), male rare type (MRT) and male absent type (MAT) (Nakasono, 1983). The MRT and MAT populations reproduce parthenogenetically; MNT populations reproduce amphimictically. In addition, MRT and MAT populations occur at more northern, cooler latitudes and have narrower host ranges than MNT populations. It is noteworthy that in Cuba, an amphimictic population of *R. reniformis* has been shown to be capable of producing viable but noninfective progeny parthenogenetically (Rodríguez-Fuentes and Añorga-Morales, 1977).

It is never possible to say with absolute certainty that a given plant genotype is a nonhost. On some genotypes, nematode reproduction may be so low that numerous root systems must be examined carefully before a single gravid female is found. From a practical standpoint, therefore, the appropriate criteria for distinguishing between hosts and non-hosts depends somewhat on the intended application. For regulatory purposes, any egg production at all can cause contamination problems in nurseries certified for this pest (Inserra *et al.*, 1991, 1994b). In contrast, a low level of reproduction would be unimportant in a resistant rotational crop if recontamination of the field by wind, water, and nematode reproduction on weed hosts were impossible to avoid.

Economic impact: Many studies have been done to estimate the impact of *R. reniformis* on crops around the world. As with other nematodes, the approaches taken have been to measure plant growth responses to a graded series of inoculum levels in pots or microplots, or measure yield responses to nematicide or crop rotation treatments. Each approach of course has its limitations. Damage levels measured in pots can differ substantially from those under field conditions, while in field plantings, many factors other than the nematode can contribute to the responses observed. As noted by Gaur and Perry (1991b), pot studies with graded inoculum levels of *R. reniformis* indicate that damage to a wide array of plants can occur at densities between 0.1 and 5 nematodes/cm^3 of soil (Acharya and Padhi, 1987; Acosta and Ayala, 1975; Ahmad, 1989; Ferraz and Sharma, 1979; Gapasin and Valdez, 1979; Gupta and Yadav, 1980; Khan and Husain, 1989b, 1990; Mishra and Gaur, 1981; Padhi and Misra, 1987; Panda and Seshadri, 1979; Rebois *et al.*, 1978; Sahoo and Padhi, 1986; Sud *et al.*, 1984; Varaprasad *et al.*, 1987).

Rotylenchulus reniformis is considered a serious problem in Upland cotton throughout the southeastern United States (Heald and Robinson, 1990) (Fig. 12) and population thresholds for nematicide application have been developed based on results of numerous field trials (Beltwide Cotton Nematode Survey, 1994; Lawrence and McLean, 1996). The agricultural university extension services in Mississippi and Alabama recommend treatment if the *R. reniformis* population density exceeds 2 nematodes/cm^3 in the spring or 10 nematodes/cm^3 in the fall or winter (Blasingame and Patel, 1987). Corresponding thresholds in Louisiana are 1 and 5 nematodes/cm^3 soil (pers. comm., C. Overstreet, Louisiana State University). Population densities exceeding all of these thresholds are commonly encountered in the Mississippi Delta production region (Lawrence and McLean, 1996), the Red River Basin (Overstreet and McGawley, 1996), and the Lower Rio Grande Valley (Robinson *et al.*, 1987). These densities are much higher than are typically encountered for *Meloidogyne* species in cotton fields (Starr *et al.*, 1993). *Rotylenchulus reniformis* does not occur in Arizona, California, and New Mexico (Heald and Robinson, 1990).

In plot experiments conducted in south Florida, positive yield response on snap bean (*Phaseolus vulgaris*) was obtained with non-fumigant nematicide (oxamyl)

Fig. 12. Stunted plants in a cotton field infested by *Rotylenchulus reniformis* in Alabama. (Courtesy of W. S. Gazaway).

treatment at population levels of 4 or more *R. reniformis*/cm^3 soil. With lower populations, use of the nematicide was not consistent in increasing snap bean yield (McSorley *et al.*, 1981b). Results of other plot experiments conducted in south Florida showed an inverse relationship between snap bean yield and the number of *R. reniformis* in the soil (McSorley, 1980). However, at the greatest population densities (9 *R. reniformis*/cm^3 of soil) the yield suppression did not exceed 25% (Fig. 13). At the population levels that usually occur in Florida soils (4-5 nematodes/cm^3 of soil), nematode damage on snap bean averages *ca.* 10% (Fig. 13) (McSorley, 1980). These results indicate that *R. reniformis* at high population densities on snap bean in Florida has less destructive effect than root-knot nematodes (*Meloidogyne* spp.). However, crop loss of greater magnitude is routinely reported for cotton growing in fields infested with *R. reniformis* in Louisiana (206,000 ha) and Mississippi (283,000 ha). Losses in these two states have been assessed as high as 40-60%, but average 15-30% (Overstreet, 1996).

On various legume and vegetable crops, particularly in India, nematicide treatment is not cost effective, and management through use of resistant and tolerant cultivars or with cultural methods, such as crop rotation, fallow, weed control, *etc.*, is preferable. In field crops, appreciable effort has been put toward the identification of resistant germplasm and the development of resistant cultivars.

Regulatory considerations: In addition to being a damaging pest of field and vegetable crops, *R. reniformis* is of economic

Fig. 12. Stunted plants in a cotton field infested by *Rotylenchulus reniformis* in Alabama. (Courtesy of W. S. Gazaway).

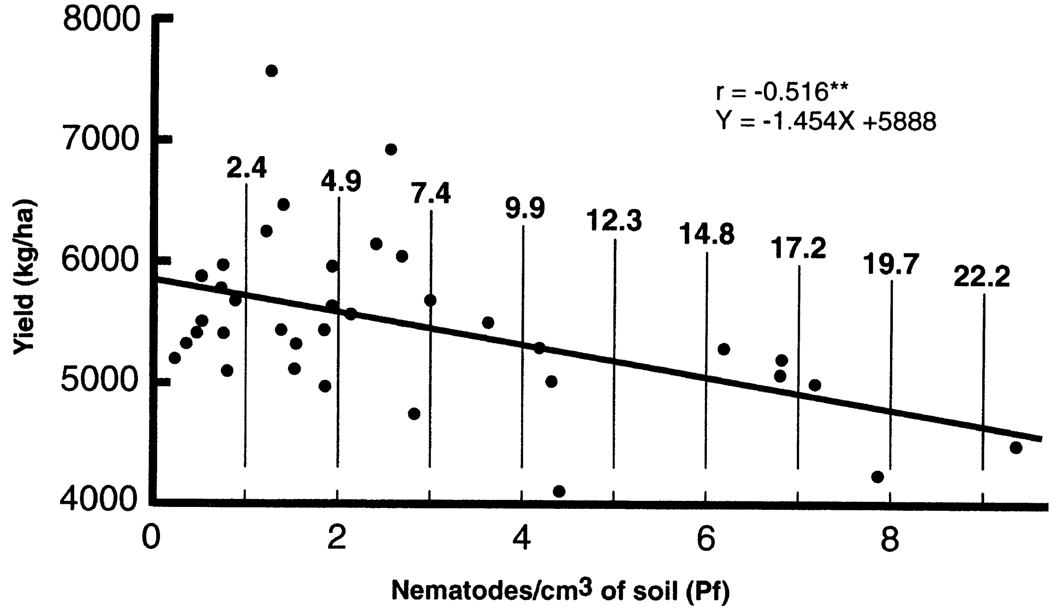

Fig. 13. Relationship of snap bean yield to final population (Pf) of *Rotylenchulus reniformis* in treated and untreated plots. Values on top of each vertical bar indicate percentage of yield loss observed at each *R. reniformis* population level compared to the chemically disinfested plots. The regression equation is based on numbers of nematodes per 100 cm^3 soil. (After McSorley, 1980).

importance to ornamental industries established in areas where the nematode is present because of the quarantine restrictions imposed by some states to plant shipments contaminated by this parasite. In the United States, the states of Arizona, California, and New Mexico enforce quarantines against the reniform nematode in order to protect their cotton industries from this pest. Chile and Switzerland list *R. reniformis* among the noxious organisms subject to quarantines.

Crop resistance: Resistant breeding lines and cultivars were tabulated by Varaprasad (1986) and updated by Gaur and Perry (1991b). We have combined this information with that gathered from other sources, omitted most species for which germplasm screening studies *per se* were not found, and deleted names of resistant cultivars or breeding lines, to conserve space (Table 4). Based on the number of genotypes examined and the number of papers published, most work has been done on Upland cotton and soybean in the United States, and on various staple legumes in India and Pakistan. The availability of sources of resistance to *R. reniformis* in these crops varies greatly. Certain cultivars of tomato and soybean, for example, have very high levels of resistance. In cowpea, a few acceptably resistant cultivars have been identified. In Upland cotton, no cultivars with high levels of resistance are available. However, several high-yielding breeding lines have been developed that are tolerant to *R. reniformis* and are adapted to the Lower Rio Grande Valley (Cook *et al.*, 1997). Four additional lines developed under Louisiana conditions have a low level of resistance and have been released for commercial development (Jones *et al.*, 1988). Incorporating resistance from related *Gossypium* species

Table 4. Studies identifying crop germplasm with resistance to *Rotylenchulus reniformis.*

- Blackgram, urdbean (*Vigna mungo* L.)
  - Routaray *et al.*, 1986
- Castor (*Ricinus communis* L.)
  - Darekar *et al.*, 1990
- Chickpea (*Cicer arietinum* L.)
  - Anver and Alam, 1990, 1995
  - Sahoo *et al.*, 1986
- Coffee (*Coffea* spp.)
  - Macedo, 1974
  - Peacock, 1956a
  - Schenck and Schenck, 1994
- Cotton and related plants (*Gossypium* spp.)
  - Beasley, 1986
  - Birchfield and Brister, 1963
  - Blasingame, 1991
  - Cook *et al.*, 1997
  - Cook *et al.*, 1996
  - Jones *et al.*, 1988
  - Khadr *et al.*, 1972
  - Minton, 1964
  - Muhammad and Jones, 1990
  - Muralidaran and Sivakumar, 1977
  - Neal, 1954
  - Shepherd, 1983
  - Yik and Birchfield, 1984
- Cowpea (*Vigna unguiculata* L.)
  - Gaur, 1986
  - Haque, 1992
  - Haque and Padmavathy, 1986
  - Khan and Husain 1988, 1989b
  - Makadia *et al.*, 1987
  - Thakar and Patel, 1985
- Horsegram (*Dolichos uniflorus* Lam.)
  - Nayak *et al.*, 1987
- Greengram, mungbean (*Phaseolus aureus* Roxb. = *Vigna radiata* (L.) R. Wilczeck)
  - Patel *et al.*, 1989a
- Papaya (*Carica papaya* L.)
  - Patel *et al.*, 1989b
- Pepper and related plants (*Capsicum* spp.)
  - Birchfield and Brister, 1962
  - Peacock, 1956a
  - Routaray *et al.*, 1988
- Pigeonpea [*Cajanus cajan* (L.) Mill]
  - Chavda *et al.*, 1988
  - Patel *et al.*, 1987
  - Thakar and Yadav, 1985, 1986, 1987
- Potato (*Solanum tuberosum* L.)
  - Montasser *et al.*, 1992
  - Rebois and Webb, 1979
- Soybean (*Glycine max* (L.) Merr.)
  - Anand, 1992
  - Birchfield and Brister, 1969
  - Birchfield and Williams, 1974
  - Birchfield *et al.*, 1971
  - Cornelius and Lawrence, 1993
  - Good, 1972
  - Hartwig and Epps, 1973, 1977
  - Hartwig *et al.*, 1988
  - Harville *et al.*, 1988
  - Lim and Castillo, 1979
  - Rebois *et al.*, 1968, 1970
  - Robbins *et al.*, 1994a, 1994b
  - Williams *et al.*, 1981
- Sweet potato [*Ipomoea batatas* (L.) Lam.]
  - Clark and Wright, 1983
  - Good, 1972
  - Martin *et al.*, 1966
- Tobacco (*Nicotiana tabacum* L.)
  - Heald and Meredith, 1987
  - Patel, 1986
- Tomato and related plants (*Lycopersicon* spp.)
  - Balasubramanian and Ramakrishnan, 1983
  - Germani, 1978b

Table 4. (Continued) Studies identifying crop germplasm with resistance to *Rotylenchulus reniformis.*

- Patel and Thakar, 1986
- Routaray *et al.*, 1986

Olive (*Olea europaea* L.)

- Al-Sayed and Abdel-Hameed, 1991
- Montasser, 1986
- Rebois *et al.*, 1973
- Subramanian *et al.*, 1993

(Yik and Birchfield, 1984) is confounded by ploidy and chromosome incompatibilities (Richmond, 1968). As discussed in the previous section on immune plants, there are additional crop species with very high levels of resistance or with immunity, including mustard (*Brassica nigra*), oats, Rhodesgrass (*Chloris gayana*), onion, sugarcane, sunn hemp (*Crotalaria juncea*) and winter wheat (*Triticum aestivum*) (Table 2).

In most cases studied, resistance to *R. reniformis* appears to be inherited, at least in part, independently from resistance to other sedentary nematodes. In Upland cotton, several commercial cultivars and various breeding lines have moderate to high levels of resistance to *Meloidogyne incognita* (Kofoid and White) Chitwood race 3. These have one or both of two relatively strong sources of resistance in their genetic backgrounds: cv. Clevewilt 6 and USDA Cotton Germplasm Collection No. SA 2516 (a wild *G. hirsutum* accession collected in 1947 in Mexico). All *M. incognita*-resistant cultivars of Upland cotton support prolific reproduction by *R. reniformis.* Levels of reproduction by *R. reniformis* vary sufficiently that some breeding lines are considered to have partial resistance; however, inheritance of resistance is complex and new sources of resistance are needed (Muhammad and Jones, 1990). In soybean, high levels of resistance to *R. reniformis* have been found and early studies indicated the same genes conferred resistance to the soybean cyst nematode (*Heterodera glycines* Ichinohe) (Rebois *et al.*, 1968). This prediction, however, has not held up in subsequent genetic studies (Anand, 1992; Birchfield *et al.*, 1971; Gilman *et al.*, 1979; Hartwig and Epps, 1977; Harville *et al.*, 1988). Two pairs of genes with unequal effects are now believed to confer resistance to *R. reniformis* in soybean (Harville, 1985; Williams *et al.*, 1981). In sweetpotato, inheritance of resistance to *R. reniformis* is linked to genes that cause tubers to crack in response to nematode attack and other factors, making tubers unmarketable (Clark and Wright, 1983; Martin, 1960).

Crop rotation and mixed cropping: Management of *R. reniformis* by rotating susceptible crops with nonhost crops has been explored in various regions but apparently has not yet been practiced on a wide scale. The extensive host range of *R. reniformis* severely restricts the options available and further limitations are imposed when other plant-parasitic nematodes or soilborne pathogens are present. Nonetheless, a number of rotation sequences have been shown to reduce *R. reniformis* populations to nondamaging levels.

Khan *et al.* (1984) in India examined seven 2-year sequences of various combinations of fallow, mung bean (*P. aureus*), carrot (*Daucus carota*), marigold (*Tagetes* sp.), okra (*Abelmoschus esculentus*), wheat, common bean (*P. vulgaris*), Egyptian clover (*T. alexandrinum*), mustard, barley, and sesbania (*Sesbania* sp.), and concluded that mung bean, sesbania, marigold, wheat, barley, and fallow were all effective against

R. reniformis without increasing populations of *Meloidogyne* sp. or *Tylenchorhynchus brassicae* Siddiqi. Haque and Gaur (1985) examined seven other rotations of vegetables in India and found that mung bean, okra, radish (*Raphanus sativus*), chickpea, pea, and maize all resulted in a rapid increase in populations of *R. reniformis* in the soil whereas mustard and sesamum (*Sesamum indicum*) reduced populations. Sivakumar *et al.* (1979) found *R. reniformis* populations to decline faster in pots containing *C. annuum* than in pots containing no plants. Populations of *R. reniformis* also have been shown to decline rapidly in pots containing bermudagrass (Singh, 1975).

Rotylenchulus reniformis has long been a serious problem in the production of pineapple (*Ananas comosus*) in Hawaii. The Hawaiian pineapple industry has now returned to a long planting cycle that includes a fallow period of 6-12 months, providing an opportunity to utilize immune or antagonistic rotational crops (Rohrback and Apt, 1986). Management of *R. reniformis* by rotating pineapple to sugarcane or pangolagrass (*Digitaria decumbens*) was done in Puerto Rico more than 30 years ago (Roman, 1964). In 1991, Caswell *et al.* examined effects of planting Rhodesgrass, pangolagrass, or sunn hemp in a pineapple field in Hawaii during the intercrop period. Rhoadesgrass reduced populations at least as well as clean fallow 3 months after planting, and populations under sunn hemp 6 months after planting were lower than those in fallow plots. Under greenhouse conditions, population reductions in pots with French marigold (*Tagetes patula*) or with either of two cultivars of Rhodesgrass were greater than in pots without plants. Ko and Schmidt (1993) found that *T. patula* also reduced populations to lower levels than those in fallow plots over a 6-month period in a Hawaiian pineapple field.

In Japan, African marigold (*Tagetes erecta*) and French marigold were compared in rotation with great burdock (*Arcticum lappa*), an important vegetable in Japan. *Tagetes patula* was found to have a strong antagonistic effect against *R. reniformis*, while *T. erecta* was a moderately good host (Nakasono, 1973).

Since there are no appreciable levels of resistance to *R. reniformis* in commercial cultivars of Upland cotton, several studies in the United States cotton belt have examined possible rotational crops. Gilman *et al.* (1978) showed that a 1-year rotation of susceptible cotton or susceptible soybean to the resistant soybean cultivar Pickett 71 was extremely effective in reducing the *R. reniformis* population and increasing the yield of the following susceptible crop. However, if the susceptible crop was cotton, high population densities were reachieved by midseason. A similar, rapid reattainment of high population levels in Upland cotton has been observed also in Israel (pers. comm., D. Orion, The Volcani Center, Bet Dagan). In the United States, maize also has been shown to be an effective rotational crop where it can be economically justified (Lawrence *et al.*, 1991; Rush *et al.*, 1996). Results of rotating maize with crops other than cotton in India have not been particularly encouraging; however, Egunjobi *et al.* (1986) found *R. reniformis* to be only one-ninth as abundant under maize as under cowpea in Nigeria.

A few studies have examined the possibility of intercropping a susceptible crop with antagonistic plants. Yassin and Ismail (1993) planted *Zinnia elegans* in pots containing tomato plants, and Siddiqui and Alam (1987) planted *Tagetes lucida* L. in pots containing tomato, eggplant (*Solanum melongena*), cabbage (*Brassica oleracea* var. *capitata*), or cauliflower. Both *Z. elegans* and *T. lucida* reduced *R. reniformis* populations compared to controls. These plants may act as trap plants or may directly suppress populations. The nematode-suppressant effects of marigold are well known. Kahn (1985) found that root leachates from five host plant species stimulated hatching, whereas leachates from onion and *Capsicum* spp. suppressed hatch of *R. reniformis* eggs.

ROTYLENCHULUS SPECIES OF UNDETERMINED ECONOMIC IMPORTANCE

Rotylenchulus borealis

This species has been reported only in Europe and Africa (Fig. 14). In Europe it has been reported from Estonia, France, Germany, Italy, Spain, and The Netherlands (Bello, 1972; Dasgupta *et al.*, 1968; Germershausen and Gunter, 1984; Ryss, 1992). Both females and males have been found. In Africa, *R. borealis* was reported in Benin, Cameroon, Central African Republic, Ghana, Ivory Coast, Kenya, Malawi, Nigeria, and Zimbabwe (Dasgupta *et al.*, 1968; Germani, 1978a; Hillocks *et al.*, 1995). It was erroneously reported from Puerto Rico (Germani, 1978a). The known hosts of this species are all herbaceous plants (Table 5).

Italian populations of *R. borealis* failed to infect Upland cotton cv. Deltapine 16, peanut (*Arachis hypogaea*) cv. Florunner, pepper cv. Yolowonder, tomato cv. Roma, and durum wheat (*Triticum durum* Desf.) cv. Creso (Vovlas and Inserra, 1982). However, *R. borealis* has been found in cotton and peanut fields in Benin, Cameroon, and Ghana (Germani, 1978a). It also has been found in citrus orchards in Spain (Bello, 1972), in vineyards in Italy (Dasgupta *et al.*, 1968), and in uncultivated land in South Africa (Kleynhans *et al.*, 1996). No host determination, however, was attempted at these sites. The life cycle of *R. borealis* is similar to that of the other reniform nematode species and requires 35-40 days (from egg to egg) at 20-25°C (Vovlas and Inserra, 1982).

Rotylenchulus macrodoratus

This species (Fig. 15) occurs only in the Mediterranean region where it has been reported in France, Greece, Israel, Italy, and Malta (Cohn and Mordechai, 1977; Inserra and Vovlas, 1980; Lamberti and Dandria, 1979; Scotto La Massese, 1973). Both females and males have been found. *Rotylenchulus macrodoratus* is known to parasitize various fruit and ornamental trees and a few herbaceous plants (Table 6).

The life cycle of *R. macrodoratus* (Fig. 16) is similar to that of other reniform

Table 5. Known hosts of *Rotylenchulus borealis*.

Common name	Scientific name
Bean cv. Harvester	*Phaseolus vulgaris* L.
Corn cv. Dekalb XL-14	*Zea mays* L.
Green pea cv. Progress	*Pisum sativum* L.
Potato cv. Alfa	*Solanum tuberosum* L.
Sorghum cv. N 12	*Sorghum bicolor* (= *vulgare*) (L.) Moench
Sweet potato (cv. undetermined)	*Ipomoea batatas* L.

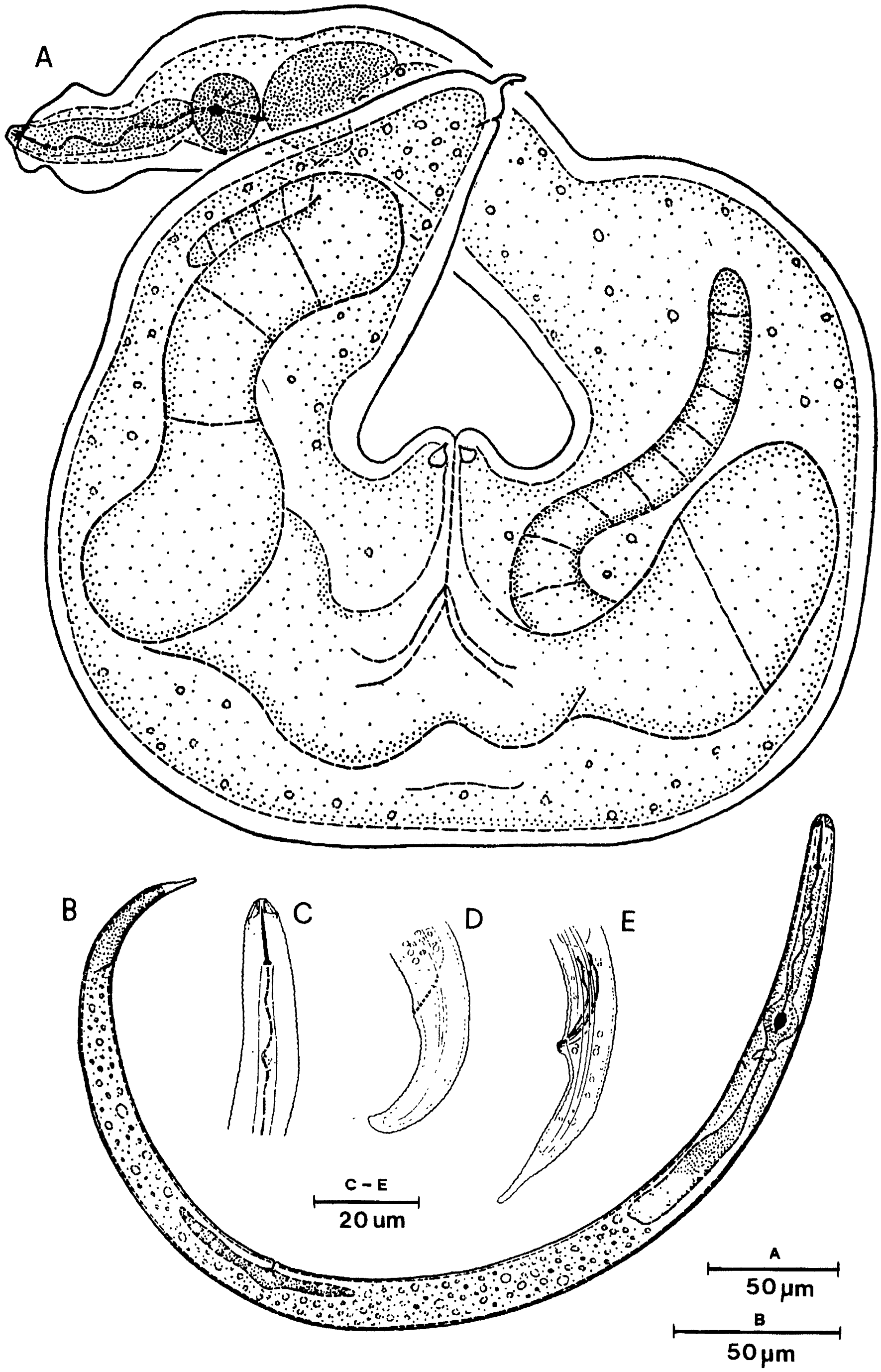

Fig. 14. Life stages of *Rotylenchulus borealis*. A) Mature female. B) Immature female. C) Anterior portion of the body of juvenile. D) Tail of juvenile. E) Tail of male. (After Loof and Oostenbrink, 1962; Dasgupta *et al.*,1968, modified).

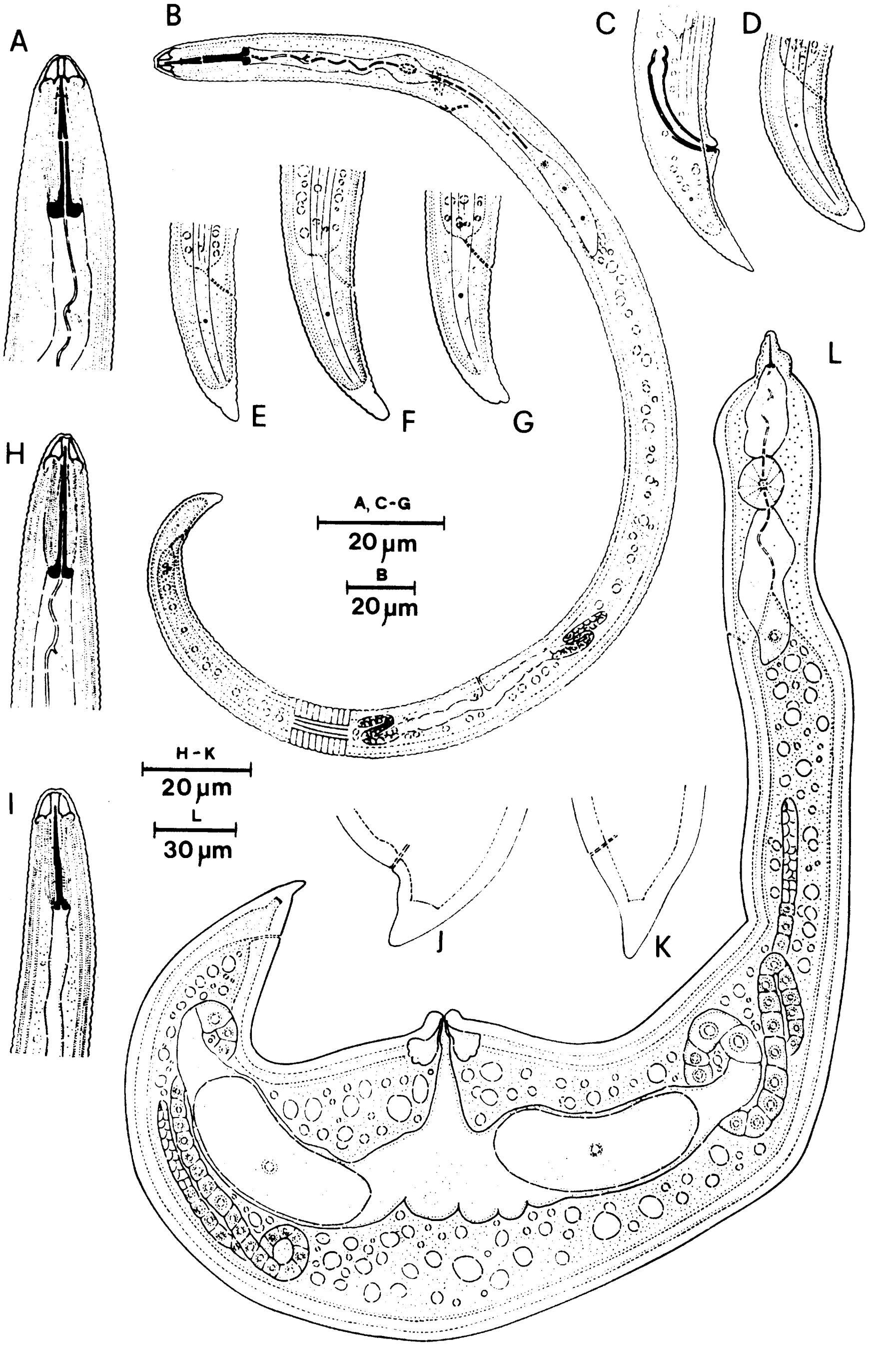

Fig.
fem
juve
et al.

Fig. 15. Life stages of *Rotylenchulus macrodoratus.* A) Anterior portion of the body of immature female. B) Immature female. C) Tail of male. D) Tail of juvenile. E-G) Tail of immature female. H) Anterior portion of the body of juvenile. I) Anterior portion of the body of male. J,K) Tail of mature female. L) Mature female. (After Dasgupta *et al.*, 1968, modified).

Table 6. Known hosts of *Rotylenchulus macrodoratus.*

Common name	Scientific name
Tree hosts	
Almond	*Prunus amygdalus* L.
Apricot	*Prunus armeniaca* L.
Carob	*Ceratonia siliqua* L.
Fig	*Ficus carica* L.
Grape	*Vitis vinifera* L.
Laurel	*Laurus nobilis* L.
Loquat	*Eriobotrya japonica* Lindl.
Oleander	*Nerium oleander* L.
Olive	*Olea europaea* L.
Oak	*Quercus calliprinos* Webb and *Q. farnetto* Ten.
Pistacio	*Pistacia vera* L.
Plum	*Prunus domestica* L.
Herbaceous hosts	
Carnation	*Dianthus caryophyllus* L.
Ivy	*Hedera ilex* L.
Large-flowered sweet William	*Dianthus barbatus* L.
Pellitory	*Parietaria officinalis* L.
Phlomis	*Phlomis fruticosa* L.
Soybean	*Glycine max* (= *hispida*) (L.) Merr.

nematode species and requires 45-55 days (from egg to egg) at 18-32°C (Inserra and Vovlas, 1980). As noted previously, the host response induced by *R. macrodoratus* is different from those of other reniform nematodes and involves the formation of a giant uninucleate cell in the root stele (Cohn, 1976; Cohn and Mordechai, 1977; Inserra and Vovlas, 1980; Vovlas and Inserra, 1976). Other reniform nematode species induce the formation of a stelar syncytium in most hosts studied.

Rotylenchulus macrosoma

This species (Fig. 17) has been found in Israel and Syria where it attacks mainly herbaceous hosts and olive (*Olea europaea*) trees (Table 7) (Cohn and Mordechai, 1988; Sikora and Greco, 1990). Both females and males have been found.

Egyptian, or Sea-island cotton (*Gossypium barbadense*) cv. Acola, pepper (*C. annuum*) cv. Maor, sorghum (*Sorghum bicolor*) cv. D2052, winter wheat (*T. aestivum*) cv. Lakhish, and sour orange (*Citrus aurantium* L.) were non-hosts of *R. macrosoma* (Cohn and Mordechai, 1988). The life cycle of *R. macrosoma* does not differ from that of other *Rotylenchulus* species and includes the induction of a syncytium in host roots (Cohn and Mordechai, 1988).

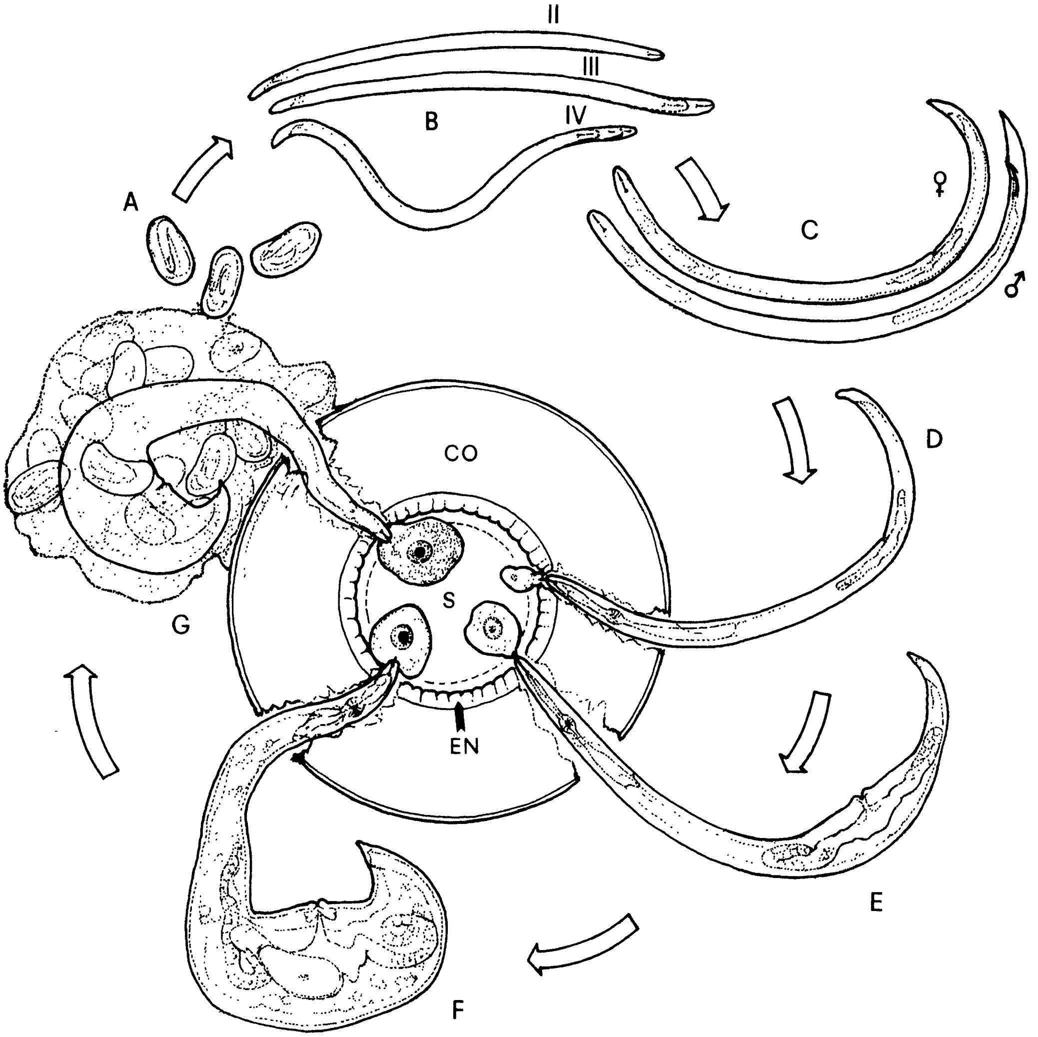

Fig. 16. Life cycle of *Rotylenchulus macrodoratus*. Eggs (A) hatch in the egg mass. Second-stage juveniles (B) emerge from eggs and initiate nematode development in the soil by molting into third-stage juveniles (B), which are followed by fourth-stage juveniles (B), immature females and non-parasitic males (C). Immature females penetrate with the anterior portion of the body into the host root (D), become sedentary, and mate. In the meantime they establish a trophic site in the stele consisting of an uninucleate giant cell, which enlarges during gonad maturation (E,F). They also produce a gelatinous matrix that flows from the vulva and covers the body. Mature females produce eggs, which remain embedded in the gelatinous matrix (G). Gelatinous matrix is not shown in D, E, and F.

Rotylenchulus parvus

This species (Figs. 18, 19) has a wide geographical distribution. It has been reported in North America (Arizona, California, and Florida) and the Caribbean Basin (St. Croix, St. Thomas, and Dominican Republic) (Dasgupta and Raski, 1968; Garcia-M., 1982; Heyns, 1976; Konicek, 1963; Lehman and Inserra, 1990; Roman

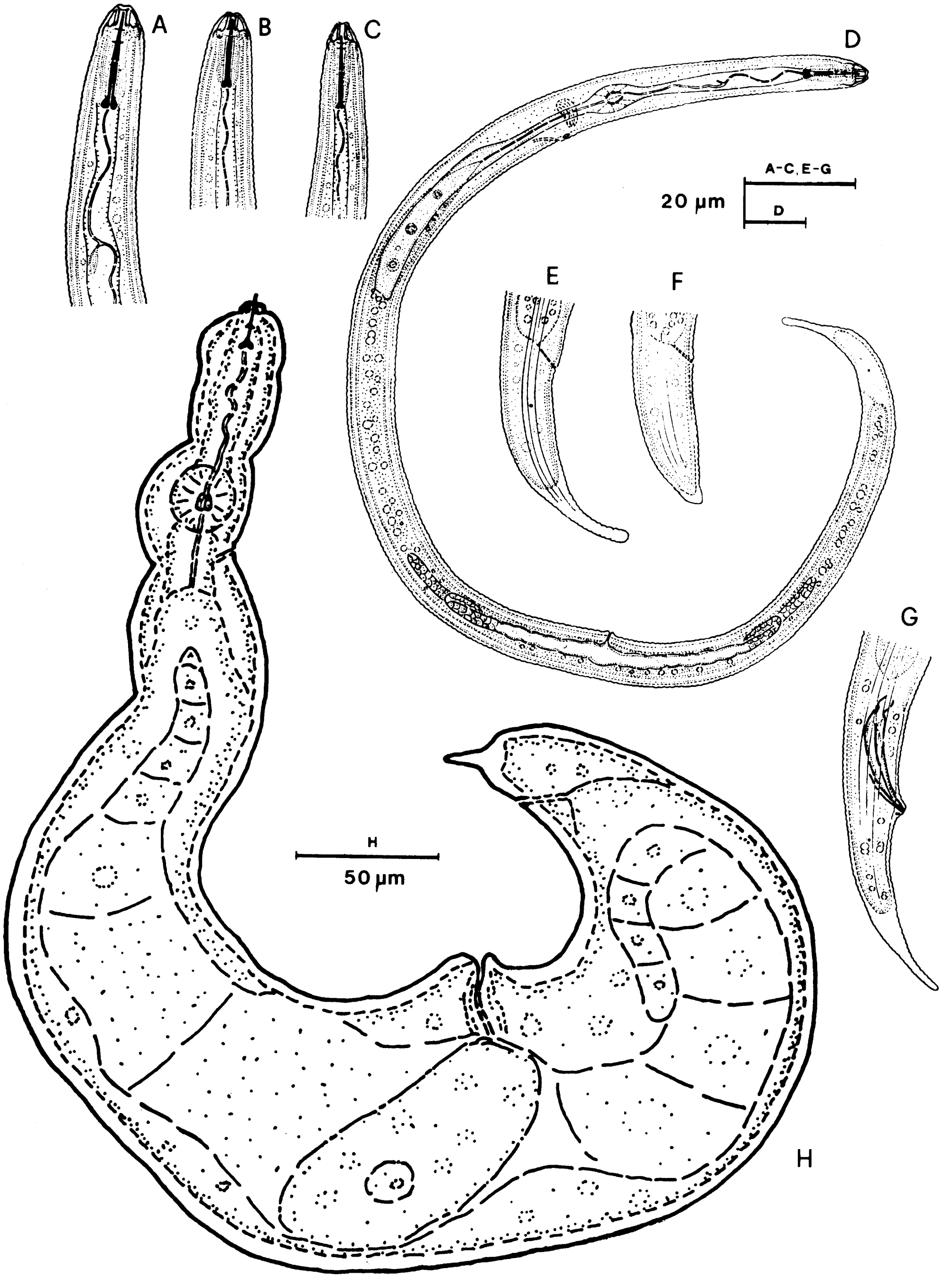

Fig. 17. Life stages of *Rotylenchulus macrosoma.* A) Anterior portion of the body of immature female. B) Anterior portion of the body of juvenile. C) Anterior portion of the body of male. D) Immature female. E) Tail of immature female. F) Tail of juvenile. G) Tail of male. H) Mature female. (After Dasgupta *et al.,* 1968, modified).

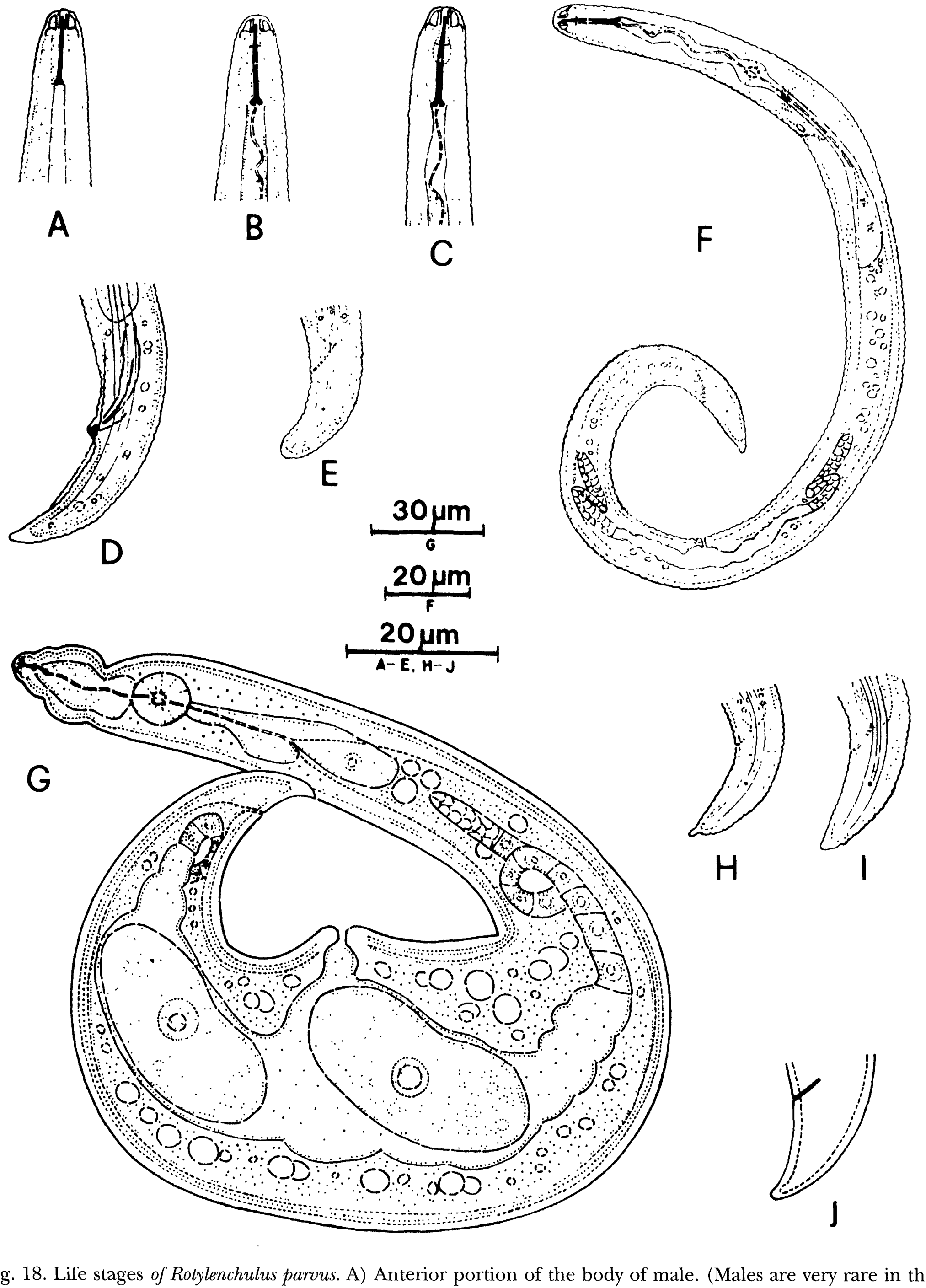

Fig. 18. Life stages *of Rotylenchulus parvus.* A) Anterior portion of the body of male. (Males are very rare in this species.) B) Anterior portion of the body of juvenile. C) Anterior portion of the body of immature female. D) Tail of male. E) Tail of juvenile. F) Immature female. G) Mature female. H,I) Tail of immature female. J) Tail of mature female. (After Dasgupta *et al.*, 1968, modified).

Table 7. Known hosts of *Rotylenchulus macrosoma.*

Common name	Scientific name
Chickpea	*Cicer arietinum* L.
Corn cv. N-170	*Zea mays* L.
Olive	*Olea europaea* L.
Potato	*Solanum tuberosum* L.
Snap bean cv. Contender	*Phaseolus vulgaris* L.
Soybean cv. Lee	*Glycine max* (= *hispida*) (L.) Merr.
Tomato cv. Hosen	*Lycopersicon esculentum* Mill.

and Grullon, 1975; Stokes, 1982), but not in South America. In Africa, *R. parvus* occurs in Ivory Coast, Kenya, Malawi, Mauritius, Monzambique, South Africa, Zaire, Zambia, and Zimbabwe (Dasgupta *et al.*, 1968; Germani, 1978a; Van den Oever and Mangane, 1992). In Asia, it has been found only in Haryana state in India (Bajaj and Bhatti, 1987). In Australia, it occurs in Queensland (Colbran, 1964). Known hosts of *R. parvus* are mainly herbaceous plants and a few fruit trees (Chinappen *et al.*, 1988; Dasgupta and Raski, 1968; Heyns, 1976; Van den Oever and Mangane, 1992) (Table 8). Maize is a good host for *R. parvus.* In contrast to results obtained with *R. reniformis,* maize was found in South Africa to be a far better host for *R. parvus* than cowpea, with populations increasing 3000% during a 3-year maize monoculture (Furstenberg and Heyns, 1978). Sugarcane is another good host of *R. parvus* in South Africa (Van den Berg and Spaull, 1981).

Rotylenchulus parvus is a parthenogenetic species (males are extremely rare), but otherwise has a life cycle similar to that of other reniform nematodes. The duration of the life cycle from egg to egg is 26-36 days at 24-28°C (Dasgupta and Raski, 1968). *Rotylenchulus parvus* is listed by the Animal and Plant Health Inspection Service of the United States Department of

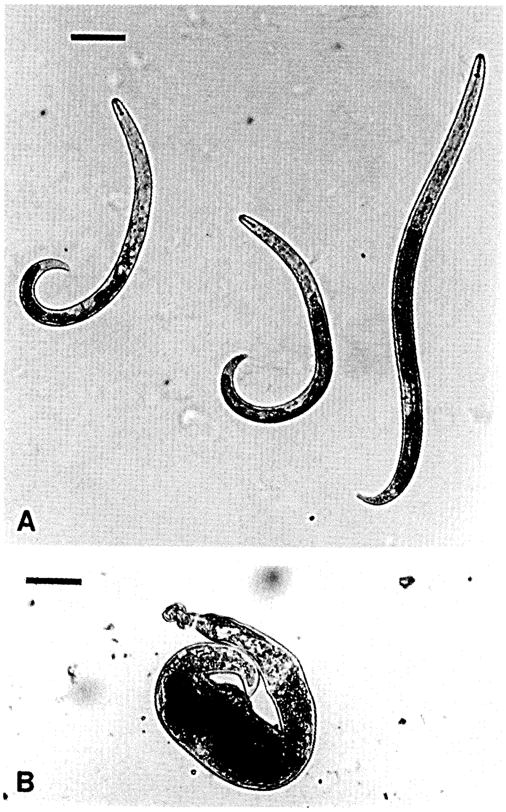

Fig. 19. Selected life stages of *Rotylenchulus parvus.* A) Immature females of *R. parvus* (two on the left) are compared with that of *R. reniformis* (one on the right), which has a longer body. B) Mature female of *R. parvus.* Scale bars = 34 μm in A and 36 μm in B. (After Lehman and Inserra, 1990).

Fig. 19. Selected life stages of *Rotylenchulus parvus*. A) Immature females of *R. parvus* (two on the left) are compared with that of *R. reniformis* (one on the right), which has a longer body. B) Mature female of *R. parvus*. Scale bars = 34 µm in A and 36 µm in B. (After Lehman and Inserra, 1990).

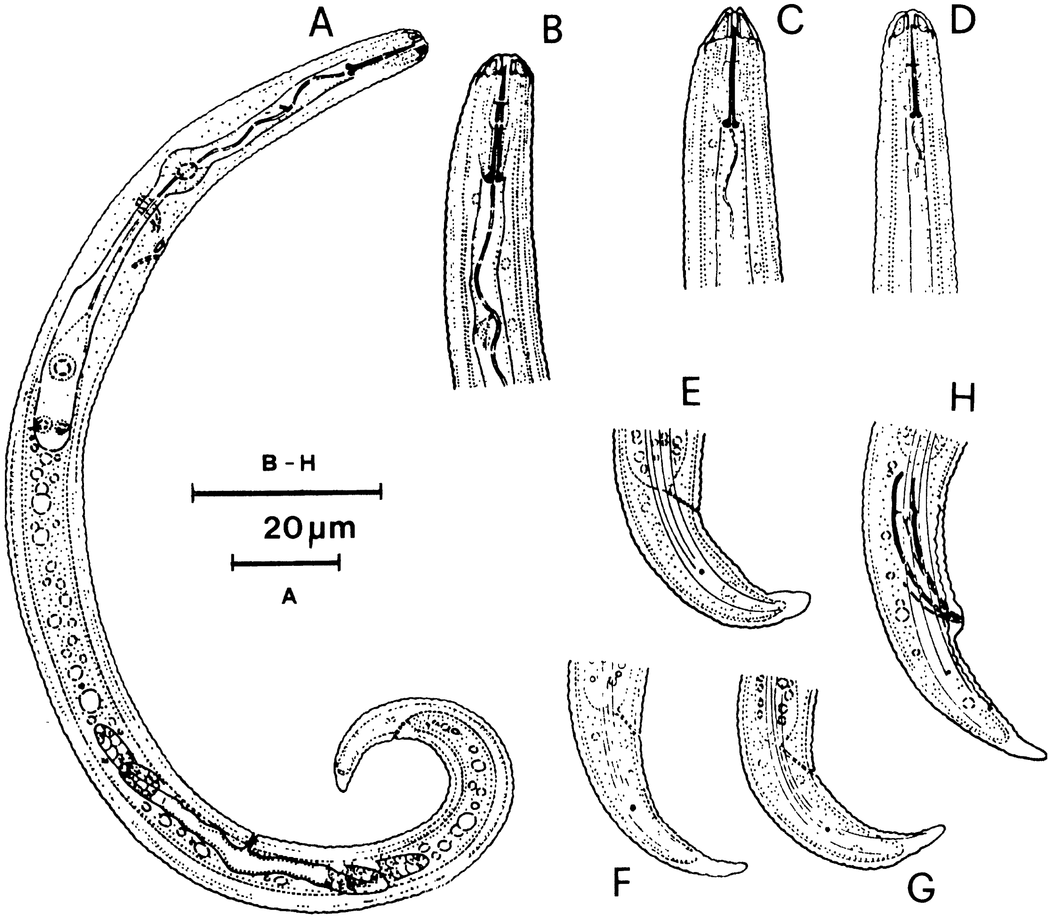

Fig. 20. Known life stages of *Rotylenchulus anamictus*. A) Immature female. B) Anterior portion of the body of immature female. C) Anterior portion of the body of juvenile. D) Anterior portion of the body of male. E) Tail of juvenile. F,G) Tail of immature female. H) Tail of male. (After Dasgupta *et al.*, 1968, modified).

Agriculture as a noxious organism subject to quarantine restriction by Brazil.

ROTYLENCHULUS SPECIES OF MINOR ECONOMIC IMPORTANCE

Rotylenchulus anamictus

This species (Fig. 20) was described from male and immature female specimens collected from the rhizosphere of *Acacia* in Merca, Somalia (Dasgupta *et al.*, 1968). It is similar to *R. parvus* from which *R. anamictus* can be separated by the presence of males and a more posterior vulva position in vermiform females (V = 62-72% *vs.* 60-66% for *R. parvus*). Swollen females, biology, and hosts of *R. anamictus* are not known.

Rotylenchulus brevitubulus

This species was described from male and immature female specimens collected from an unidentified shrub in the savanna

Table 8. Known hosts of *Rotylenchulus parvus.*

Common name	Scientific name
Barley	*Hordeum vulgare* L.
Bermuda grass	*Cynodon dactylon* (L.) Pers.
Corn	*Zea mays* L.
Upland cotton	*Gossypium hirsutum* L.
Cowpea	*Vigna unguiculata* (L.) Walp
Macadamia	*Macadamia* sp.
Pearl millet	*Pennisetum americanum* (= *glaucum*) (L.) K. Schum.
Papaya	*Carica papaya* L.
Potato	*Solanum tuberosum* L.
Sugarcane	*Saccharum officinarum* L.
Sunn hemp	*Crotalaria juncea* L.
Tobacco	*Nicotiana tabacum* L.
Thyme	*Thymus* sp.
Tomato	*Lycopersicon esculentum* Mill.

of Grunau, in west South Africa/Namibia (Van den Berg and Spaull, 1981) (Fig. 21). It has juveniles with a bifurcate tail tip unlike the undivided tail tip of the juveniles of other reniform nematodes. The distance between dorsal esophageal gland orifice and the stylet base of immature females is < 10 μm (6.0-7.5 μm), whereas it is > 10 μm for immature females of other *Rotylenchulus* species. Swollen females, biology, and hosts of *R. brevitubulus* are unknown.

Rotylenchulus clavicaudatus

This species was described without swollen females from specimens collected from the rhizosphere of *Strelitzia* sp. in Port St. Johns, Transkei, South Africa (Dasgupta *et al.*, 1968) (Fig. 22). Additional specimens and one swollen female were collected several years later from a sugarcane field at Mount Edgecombe, South Africa (Van den Berg and Spaull, 1981). This species has juvenile and female stages with a distinct clavate tail tip. Males have both clavate and tapered tail tip. Biology and hosts of *R. clavicaudatus* are unknown.

Rotylenchulus leptus

This species (Fig. 23) was described from immature female specimens collected from the rhizosphere of *Bambusa* sp. at Gwela in southern Zimbabwe (Dasgupta *et al.*, 1968). Additional specimens were found in cultivated and uncultivated land in South Africa (Kleynhans *et al.*, 1996). It is apparently parthenogenetic and is very similar to *R. parvus*. It can be separated from *R. parvus* by its longer hyaline portion (h) of the immature female tail (h = 3-7 μm vs. < 3 μm for *R. parvus*). Swollen females, biology, and hosts of *R. leptus* are not known.

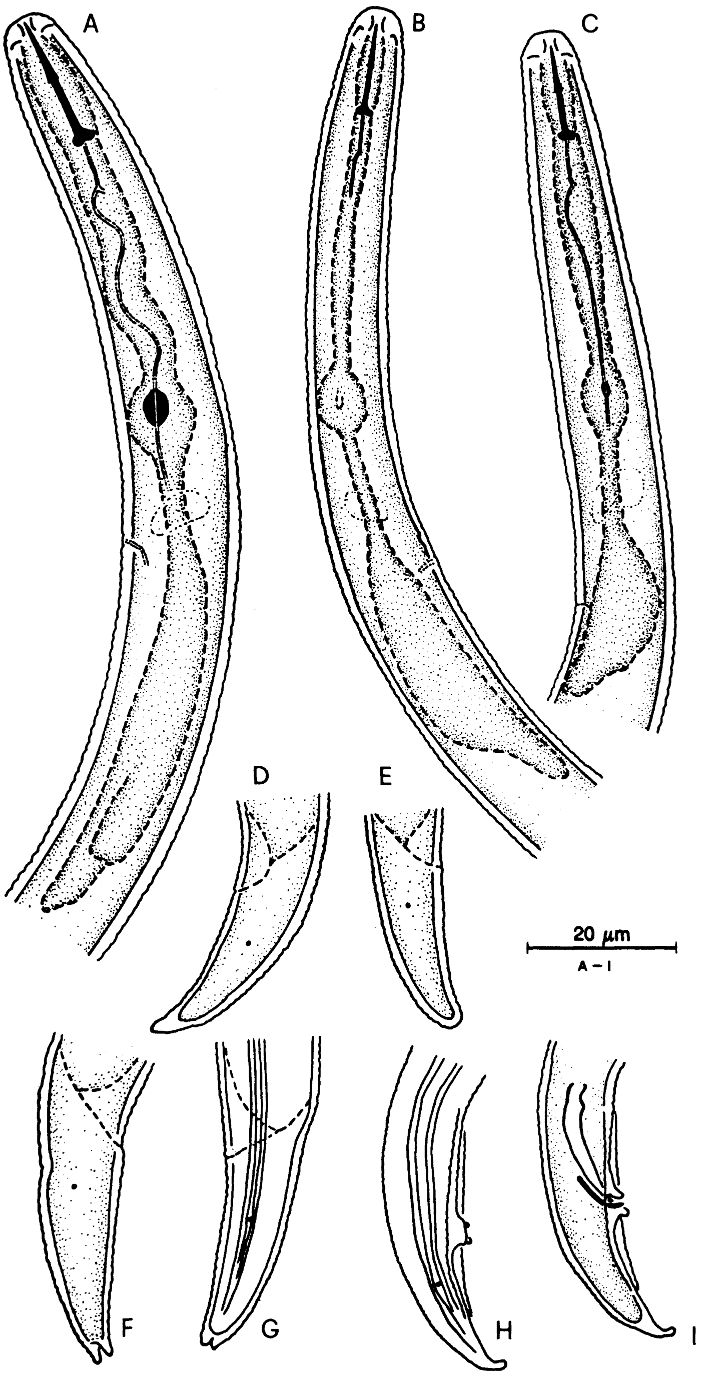

Fig. 21. Known life stages of *Rotylenchulus brevitubulus*. A) Anterior portion of the body of immature female. B) Anterior portion of the body of male. C) Anterior portion of the body of juvenile. D,E) Tail of immature female. F,G) Bifurcate tail of juvenile. H,I) Tail of male. (After Van Den Berg, 1990, modified).

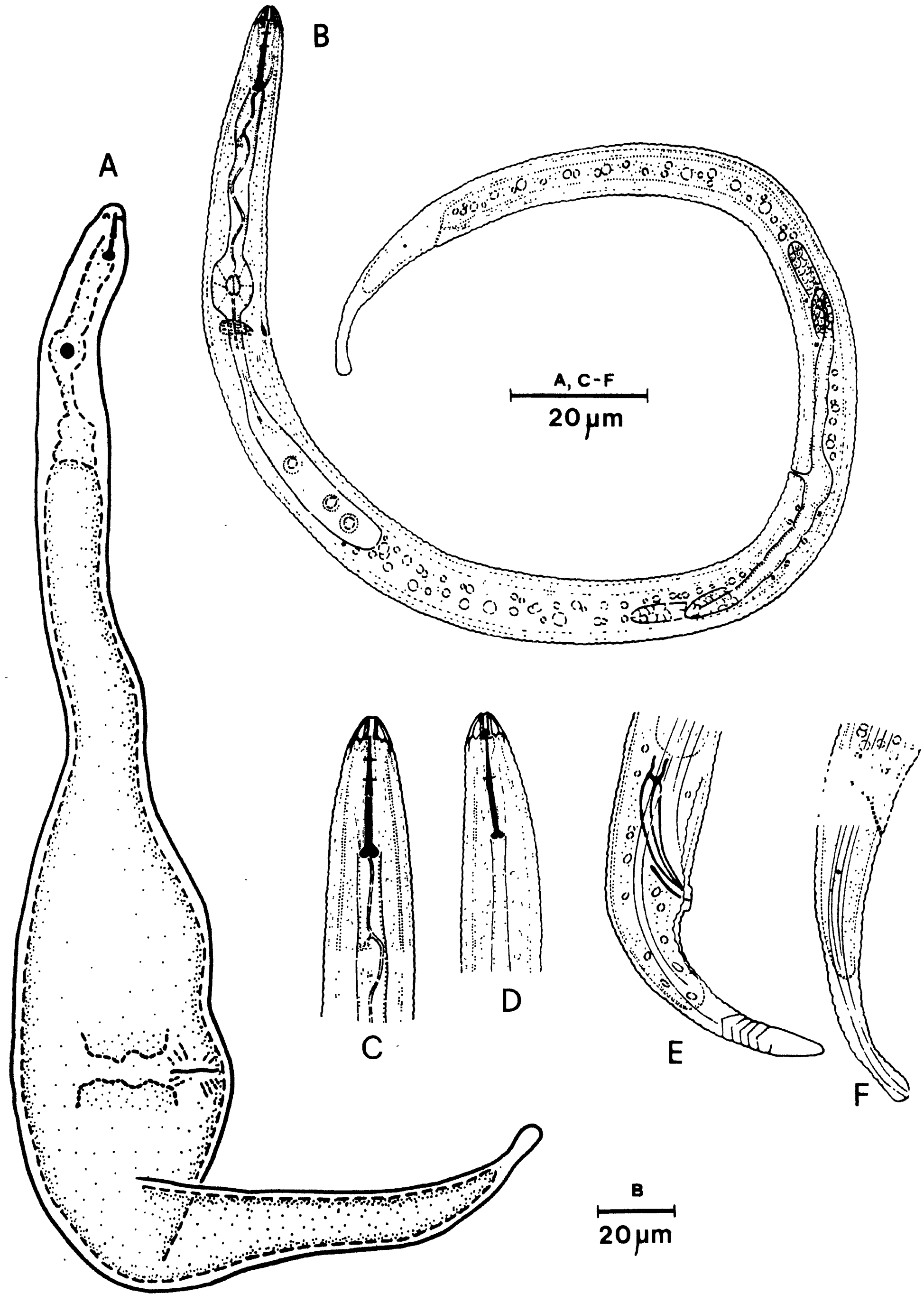

Fig. 22. Life stages of *Rotylenchulus clavicaudatus*. A) Mature female. B) Immature female. C) Anterior portion of the body of immature female. D) Anterior portion of the body of male. E) Tail of male. F) Tail of immature female. (After Dasgupta *et al.*, 1968, and Van Den Berg and Spaull, 1981, modified).

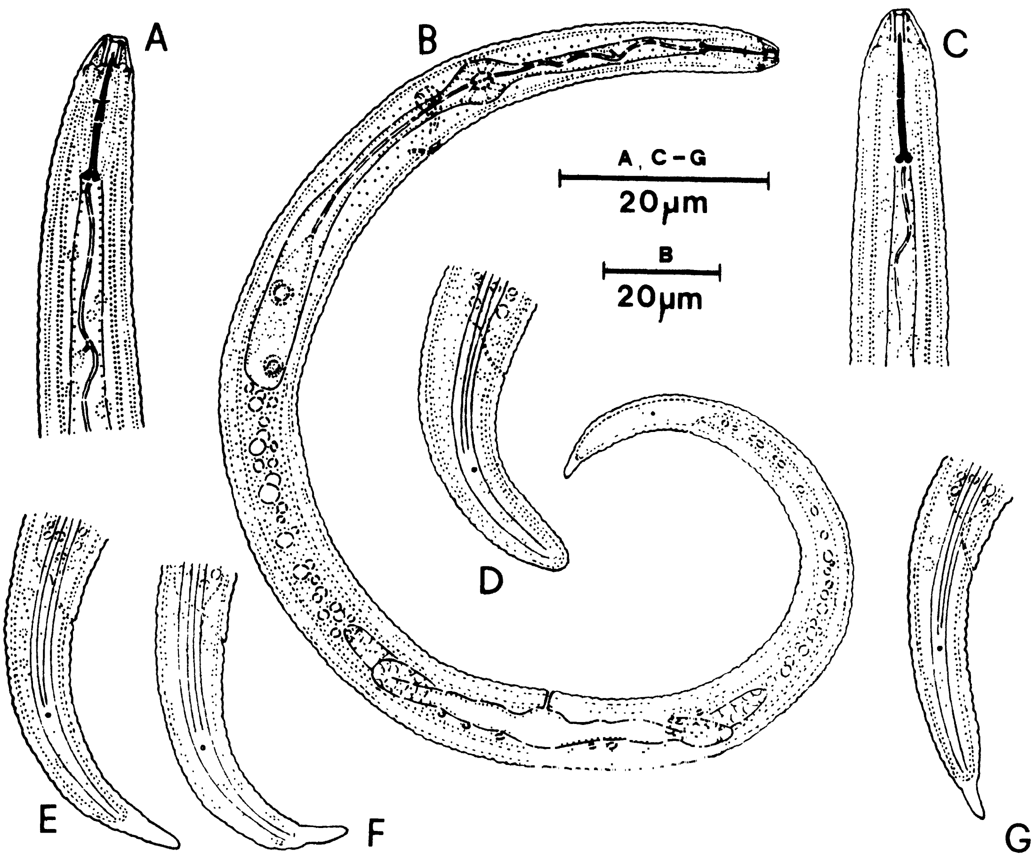

Fig. 23. Known life stages of *Rotylenchulus leptus.* A) Anterior portion of the body of immature female. B) Immature female. C) Anterior portion of the body of juvenile. D) Tail of juvenile. E-G) Tail of immature female. (After Dasgupta *et al.,* 1968, modified).

Rotylenchulus sacchari

This species was described from male and immature female specimens collected from a sugarcane field in Heatonville, Natal, South Africa (Van den Berg and Spaull, 1981) (Fig. 24). The immature females have a longer stylet than those of other reniform nematodes (29.0-32.5 µm vs. < 27 µm for other reniform nematodes) and a bluntly rounded tail terminus. Swollen females, biology, and hosts are not known.

ACKNOWLEDGEMENT

The authors thank Dr. Nancy C. Coile for providing Latin names and taxonomic authors for plant taxa. Appreciation is also expressed to Drs. A. Coomans, R. McSorley, and C. Overstreet for suggestions and valuable material provided and to Mrs. A. Smith for technical assistance. The following scientific societies kindly permitted the use of illustrations published in their journals: European Society of Nematologists, publisher of Nematologica; Helmintholog-

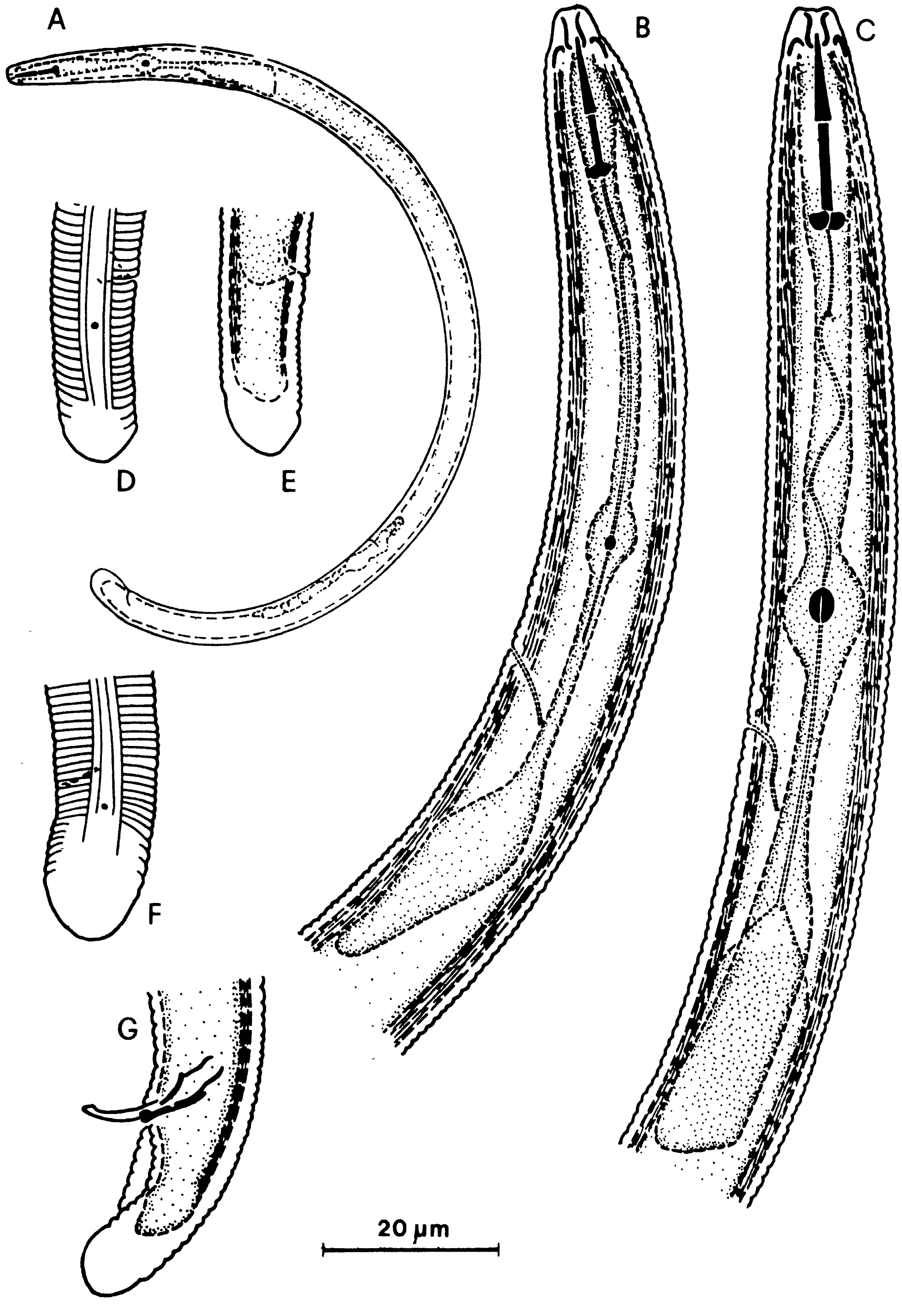

Fig. 24. Known life stages of *Rotylenchulus sacchari*. A) Immature female. B) Anterior portion of the body of male. C) Anterior portion of immature female. D,E) Tail of juvenile. F) Tail of immature female. G) Tail of male. (After Van den Berg and Spaull, 1981, modified).

ical Society of Washington, publisher of the Proceedings of the Helminthological Society of Washington; the Plant Protection Research Institute of Pretoria, South Africa, publisher of Phytophylactica; Society of Nematologists, publisher of the Journal of Nematology; and the Soil and Crop Science Society of Florida, publisher of Soil and Crop Science Society of Florida Proceedings.

LITERATURE CITED

ACHARYA, A., and N. N. PADHI. 1987. Population threshold of *Rotylenchulus reniformis* in relation to its disease intensity on betelvine. International Nematology Network Newsletter 4:21-23.

ACOSTA, N., and A. AYALA. 1975. Pathogenicity of *Pratylenchus coffeae, Scutellonema bradys, Meloidogyne incognita,* and *Rotylenchulus reniformis* on *Dioscorea rotundata.* Journal of Nematology 7:1-6.

AHMAD, S. 1989. Pathogenicity of reniform nematode, *Rotylenchulus reniformis* on papaya (*Carica papaya*). International Nematology Network Newsletter 6:16-17.

AL-SAYED, A. A., and S. H. ABDEL-HAMEED. 1991. Resistance and susceptibility of olives to *Meloidogyne incognita* and *Rotylenchulus reniformis.* Annals of Agricultural Science, Moshtohor 29:1221-1226.

ANAND, S. C. 1992. Registration of 'Hartwig' soybean. Crop Science 32:1069-1070.

ANONYMOUS. 1978. Annual Report. International Institute of Tropical Agriculture: Ibadan, Nigeria.

ANVER, S., and M. M. ALAM. 1990. Susceptibility of chickpea accessions to the reniform nematode *Rotylenchulus reniformis.* Tests of agrochemicals and cultivars 11. Annals of Applied Biology 116:94-95.

ANVER, S., and M. M. ALAM. 1995. Reaction of some chickpea accessions to the reniform nematode *Rotylenchulus reniformis.* Annals of Plant Protection Sciences 3:52-55.

ARTERO, J., A. BELLO, and A. GOMEZ BARCINA. 1977. *Rotylenchulus reniformis* Linford et Oliveira, 1940 (Nematoda: Rotylenchulinae) en España. Nematologia Mediterranea 5:247-251.

AYALA, A. 1962. Pathogenicity of the reniform nematode on various hosts. Journal of Agriculture of the University of Puerto Rico 46:73-82.

AYALA, A., and C. T. RAMIREZ. 1964. Host-range, distribution, and bibliography of the reniform nematode, *Rotylenchulus reniformis,* with special reference to Puerto Rico. Journal of Agriculture of the University of Puerto Rico 48:141-161.

BADRA, T., and S. A. ISMAIL. 1981. Accelerating the role of phenylalanine in shunting sex differentiation of *Rotylenchulus reniformis* by means of some nutrient formulae. Revue de Nématologie 4:209-212.

BADRA, T., and M. M. KHATTAB. 1982. Chemically induced resistance to *Rotylenchulus reniformis* by ethephon growth regulant and relevant pathometabolites in mango seedlings. Nematologia Mediterranea 10:49-56.

BAJAJ, H. K., and D. S. BHATTI. 1987. *Rotylenchulus parvus,* a new record of reniform nematode from India. International Nematology Network Newsletter 4:25-26.

BALASUBRAMANIAN, P., and C. RAMAKRISHNAN. 1983. Resistance to the reniform nematode *Rotylenchulus reniformis* in tomato. Nematologia Mediterranea 11:203-204.

BEASLEY, J. P. 1986. Evaluation of cotton *Gossypium hirsutum* L., genotypes for resistance to the reniform nematode *Rotylenchulus reniformis* Linford and Oliveira. Dissertation Abstracts, B 47:856.

BELLO, A. 1972. *Rotylenchulus borealis* en los cultivos de agrios (*Citrus* sp.) del levante español. Nematropica 2:25.

BELTWIDE COTTON NEMATODE SURVEY (USA). 1994. Cotton nematodes, your hidden enemies. Publication No. 11184. The Cotton Foundation and Rhône-Poulenc: Research Triangle Park, NC, USA.

BIRCHFIELD, W. 1962. Host-parasite relations of *Rotylenchulus reniformis* on *Gossypium hirsutum.* Phytopathology 52:862-865.

BIRCHFIELD, W. 1972. Differences in host-cell responses to the reniform nematode. Phytopathology 62:747 (Abstract).

BIRCHFIELD, W., and L. R. BRISTER. 1962. New hosts and nonhosts of reniform nematode. Plant Disease Reporter 46:683-685.

BIRCHFIELD, W., and L. R. BRISTER. 1963. Susceptibility of cotton and relatives to reniform nematode in Louisiana. Plant Disease Reporter 47:990-992.

BIRCHFIELD, W., and L. R. BRISTER. 1969. Reaction of soybean varieties to the reniform nematode *Rotylenchulus reniformis.* Plant Disease Reporter 53:999-1000.

BIRCHFIELD, W., and W. J. MARTIN. 1967. Reniform nematode survival in air-dried soil. Phytopathology 57:804 (Abstract).

BIRCHFIELD, W., and C. WILLIAMS. 1974. Effects of nematicides and resistant soybean varieties on reniform nematode populations and soybean yields. Proceedings of the American Phytopathological Society 1:70 (Abstract).

BIRCHFIELD, W., C. WILLIAMS, E. E. HARTWIG, and L. R. BRISTER. 1971. Reniform nematode resistance in soybeans. Plant Disease Reporter 55:1043-1045.

BIRD, A. F. 1983. Growth and moulting in nematodes: Changes in the dimensions and morphology of *Rotylenchulus reniformis* from start to finish of moulting. International Journal for Parasitology 13:201-206.

BIRD, A. F. 1984. Growth and moulting in nematodes: Moulting and development of the hatched larva of *Rotylenchulus reniformis.* Parasitology 89:107-119.

BISHNOI, S. P., and B. S. YADAV. 1989. Effect of some host plants on the biology of *Rotylenchulus reniformis* Linford and Oliveira, 1940. International Nematology Network Newsletter 6:10-11.

BLASINGAME, D. 1991. Varietal reaction to the reniform nematode of cotton. Proceedings, National Cotton Council Beltwide Cotton Conferences, 1991. 1:180.

BLASINGAME, D., and M. V. PATEL. 1987. A population and distribution survey of cotton nematodes in Mississippi. Plant Disease Dispatch, January 18, 1987. Mississippi Cooperative Extension Service: Mississippi State, MS, U.S.A.

CARTER, C. H., E. C. McGAWLEY, and J. S. RUSSIN. 1995. Reproduction of *Rotylenchulus reniformis* on weed species common to Louisiana soybean fields. Journal of Nematology 27:494-495 (Abstract).

CARTER, W. W. 1981a. Onion as a host of *Rotylenchulus reniformis.* Journal of Nematology 13:433-434.

CARTER, W. W. 1981b. Resistance and resistant reaction of *Gossypium arboreum* to the reniform nematode, *Rotylenchulus reniformis.* Journal of Nematology 13:368-374.

CASTILLO, M. B., M. S. ALEJAR, and J. S. LITSINGER. 1977. Pathological reactions and yield loss of mung bean to known populations of *Rotylenchulus reniformis* and *Meloidogyne acrita.* Philippine Agriculturist 61:12-24.

CASWELL, E. P., J. DEFRANK, W. J. APT, and C. S. TANG. 1991. Influence of nonhost plants on population decline of *Rotylenchulus reniformis.* Journal of Nematology 23:91-98.

CHAVDA, J. C., B. A. PATEL, and D. J. PATEL. 1988. Screening of pigeonpea lines to *Rotylenchulus reniformis.* International Nematology Network Newsletter 5:28-29.

CHINAPPEN, M., P. JOKHUN, and F. LAMBERTI. 1988. A decline of thyme associated with *Rotylenchulus parvus* in Mauritius. Nematologia Mediterranea 16:233-234.

CHRISTIE, J. R. 1959. Plant Nematodes. Their Bionomics and Control. Agricultural Experiment Station, University of Florida. Gainesville, FL, U.S.A.

CLARK, C. A., and V. L. WRIGHT. 1983. Effect and reproduction of *Rotylenchulus reniformis* on sweet potato selections. Journal of Nematology 15:198-203.

COATES-BECKFORD, P. L., and M. J. PEREIRA. 1992. Survey of root-inhabiting microorganisms on declining breadfruit (*Artocarpus atilis*) in Jamaica. Nematropica 22:55-63.

COHN, E. 1973. Histology of the feeding site of *Rotylenchulus reniformis.* Nematologica 19:455-458.

COHN, E. 1976. Cellular changes induced in roots by two species of the genus *Rotylenchulus.* Nematologica 22:169-173.

COHN, E., and M. MORDECHAI. 1977. Uninucleate giant cell induced in soybean by the nematode *Rotylenchulus macrodoratus.* Phytoparasitica 5:85-93.

COHN, E., and M. MORDECHAI. 1988. Morphology and parasitism of the mature female of *Rotylenchulus macrosomus.* Revue de Nématologie 11:385-389.

COLBRAN, R. C. 1964. Studies on plant and soil nematodes. 7. Queensland records of the order Tylenchida and the genera *Trichodorus* and *Xiphinema.* Journal of Agricultural Science 21:77-123.

COOK, C. G., L. N. NAMKEN, and A. F. ROBINSON. 1997. Registration of N220-1-91, N222-1-91, N320-2-91, and N419-1-91 nematode resistant cotton germplasm. Crop Science 37:1028-1029.

COOK, C. G., A. F. ROBINSON, and L. N. NAMKEN. 1997. Tolerance to *Rotylenchulus reniformis* and resistance to *Meloidogyne incognita* race 3 in high-yielding breeding lines of Upland cotton. Journal of Nematology 29:322-328.

CORNELIUS, J. J., and G. W. LAWRENCE. 1993. Evaluation of soybean cultivars for resistance to reniform nematode. Phytopathology 83:1417.

CORRELL, D. S., and M. C. JOHNSTON. 1979. Manual of the vascular plants of Texas. University of Texas: Dallas.

DAREKAR, K. S., N. L. MHASE, and S. S. SHELKE. 1990. Susceptibility of castor varieties to reniform nematode, *Rotylenchulus reniformis* Linford and Oliveira, 1940. Current Nematology 1:67-68.

DASGUPTA, D. R., and D. J. RASKI. 1968. The biology of *Rotylenchulus parvus.* Nematologica 14:429-440.

DASGUPTA, D. R., D. J. RASKI, and S. A. SHER. 1968. A revision of the genus *Rotylenchulus* Linford and Oliveira, 1940 (Nematoda: Tylenchidae). Proceedings of the Helminthological Society of Washington 35:169-172.

DASGUPTA, D. R., and A. R. SESHADRI. 1971a. Reproduction, hybridization and host adaptation in physiological races of the reniform nematode, *Rotylenchulus reniformis.* Indian Journal of Nematology 1:128-144.

DASGUPTA, D. R., and A. R. SESHADRI. 1971b. Races of the reniform nematode, *Rotylenchulus reniformis* Linford and Oliveira, 1940. Indian Journal of Nematology 1:21-24.

EDMUNDS, J. E. 1971. Association of *Rotylenchulus reniformis* with 'Robusta' banana and *Commelina* sp. roots in the Windward Islands. Tropical Agriculture (Trinidad) 48:55-61.

EGUNJOBI, O. A., P. T. AKONDE, and F. E. CAVENESS. 1986. Interaction between *Pratylenchus sefaensis, Meloidogyne javanica* and *Rotylenchulus reniformis* in sole and mixed crops of maize and cowpea. Revue de Nématologie 9:61-70.

EL-SHERIF, M., and M. EMBABI. 1975. The reniform nematode on jasmine in Egypt. Plant Disease Reporter 59:65.

EL-SHERIF, M. S., S. L. HAFIZ, and B. A. OTEIFA. 1973. Effect of *Rotylenchulus reniformis* infection on the phenolic contents of cotton, *Gossypium barbadense.* Nematologia Mediterranea 1:111-114.

FARAHAT, A. A., and A. M. KHEIR. 1983. Comparative histopathogenesis of certain leguminous crops infected with *Rotylenchulus reniformis.* Pakistan Journal of Nematology 1:57-61.

FERRAZ, E. C. A., and R. D. SHARMA. 1979. Interaction and pathogenicity of *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, 1949, and *Rotylenchulus reniformis* Linford & Oliveira, 1940 on black pepper. Review Theobroma (Brasil) 9:45-53.

FERRAZ, L. C. C., A. R. MONTEIRO, and M. M. INOMOTO. 1989. Reaction of Barbados cherry to seven phytonematode species in Brazil. Nematologia Brasileira 13:39-49.

FURSTENBERG, J. P., and J. HEYNS. 1978. The effect of cultivation on nematodes. Part I. *Rotylenchulus parvus.* Phytophylactica 10:77-80.

GAO, S. R. 1993. Preliminary report of investigation on *Rotylenchulus reniformis* from infected roots of *Euphorbia milii.* Journal of Shandong Agricultural University 24:349-350.

GAPASIN, R. M., and R. B. VALDEZ. 1979. Pathogenicity of *Meloidogyne* spp. and *Rotylenchulus reniformis* on sweet potato. Annals of Tropical Research 1:20-25.

GARCIA-M., R. 1982. Plant parasitic nematodes of the U. S. Virgin Islands. Journal of Nematology 14:441 (Abstract).

GAUR, H. S. 1986. Invasion and reproduction of the reniform nematode on some cultivars of cowpea and greengram. International Nematology Network Newsletter 3:8-10.

GAUR, H. S. 1988. Dissemination and mode of survival of nematodes in dust storms. Indian Journal of Nematology 18:84-98.

GAUR, H. S., and R. N. PERRY. 1991a. The role of the moulted cuticles in the desiccation survival of adults of *Rotylenchulus reniformis.* Revue de Nématologie 14:491-496.

GAUR, H. S., and R. N. PERRY. 1991b. The biology and control of the plant parasitic nematode *Rotylenchulus reniformis.* Agricultural Zoology Reviews 4:177-212.

GERMANI, G. 1978a. Caractères mopho-biométriques de trois espècies ouest-africanes de *Rotylenchulus* Linford & Oliveira, 1940 (Nematoda-Tylenchida). Revue de Nématologie 1:241-250.

GERMANI, G. 1978b. Tests preliminaires de sensibilité de deux cultivars de tomate et d'un cultivar d'arachide a deux souches de *Rotylenchulus reniformis* (Nematoda: tylenchida). Revue de Nématologie 1:111-112.

GERMERSHAUSEN, K., and P. GUNTHER. 1984. *Rotylenchulus borealis* Loof and Oostenbrink, 1962 in der DDR. Nachrichtemblatt für den Pflanzenschutzdienst in der DDR 38:91.

GILMAN, D. F., J. E. JONES, C. WILLIAMS, and W. BIRCHFIELD. 1978. Cotton-soybean rotation for control of reniform nematodes. Louisiana Agriculture 21:10-11.

GILMAN, D. F., J. G. MARSHALL, J. G. RABB, J. L. LAWRENCE, D. J. BOQUET, and J. L. BARTLESON. 1979. Performance of soybean varieties in Louisiana, 1976-78. Louisiana Agriculture 22:4-5.

GNANAPRAGASAM, N. C., V. ARIYARATNAM, and N. NAVARATNE. 1987. *Rotylenchulus reniformis,* the new nematode species causing damage to tea in Sri Lanka. Tea Bulletin 7:34-38.

GNANAPRAGASAM, N. C., A. A. C. KARUNARATNE, and V. T. ANPALAGAN. 1989. Susceptibility/resistance of weeds to pathogenic nematodes of tea. Tea Bulletin 9:3-10.

GOOD, J. M. 1972. Management of plant parasitic nematode populations. Pp. 109-127 *in* Proceedings, Tall Timbers Conference on Ecological Animal Control by Habitat Management, Tallahassee, Florida, 24-25 February 1972.

GOULART, A. M. C., and A. R. MONTEIRO. 1995. Resistance of *Citrus limonia* to *Rotylenchulus reniformis.* Nematologia Brasileira 19:86-88.

GUPTA, D. C., and B. S. YADAV. 1980. Pathogenicity of *Rotylenchulus reniformis* on cowpea. Nematologia Mediterranea 8:91-93.

HAQUE, M. M. 1992. Reaction of cowpea cultivars to *Rotylenchulus reniformis.* Afro-Asian Nematology Network 1:36.

HAQUE, M. M., and H. S. GAUR. 1985. Effect of multiple cropping sequences on the dynamics of nematode population and crop performance. Indian Journal of Nematology 15:262-263 (Abstract).

HAQUE, M. M., and P. V. PADMAVATHY. 1986. On the multiplication of *Rotylenchulus reniformis* in susceptible and resistant cultivars of cowpea. Indian Journal of Nematology 15:223-225.

HAQUE, M. S., and M. C. MUKHOPADHYAYA. 1980. Effects of EDTA on *Rotylenchulus reniformis* on castor. Nematologica 26:503-504.

HARTWIG, E. E., and J. M. EPPS. 1973. Registration of 'Forrest' soybeans. Crop Science 13:287.

HARTWIG, E. E., and J. M. EPPS. 1977. Registration of Centennial soybeans (Reg. No. 114). Crop Science 17:979.

HARTWIG, E. E., K. HINSON, and A. SCOTT. 1988. Registration of 'Padre' soybean. Crop Science 28:1025.

HARVILLE, B. G. 1985. Genetic resistance to reniform nematodes in soybeans. Plant Disease 69:587-589.

HARVILLE, B. G., W. M. ELKINS, W. HALL, and M. A. GREEN. 1988. Registration of 'Gregg' soybean. Crop Science 28:196.

HEALD, C. M. 1975. Pathogenicity and histopathology of *Rotylenchulus reniformis* infecting cantaloupe. Journal of Nematology 7:149-152.

HEALD, C. M., and M. D. HEILMAN. 1971. Interaction of *Rotylenchulus reniformis*, soil salinity, and cotton. Journal of Nematology 3:179-182.

HEALD, C. M., and R. N. INSERRA. 1988. Effect of temperature on infection and survival of *Rotylenchulus reniformis*. Journal of Nematology 20:356-361.

HEALD, C. M., R. N. INSERRA, and N. VOVLAS. 1988. Parasitism and reproduction of *Meloidogyne incognita* and *Rotylenchulus reniformis* on cantaloupe in two soils. Nematropica 18:53-58.

HEALD, C. M., and J. A. MEREDITH. 1987. Response of three tobacco cultivars to three *Rotylenchulus reniformis* populations. Nematropica 17:95-98.

HEALD, C. M., and A. F. ROBINSON. 1990. Survey of current distribution of *Rotylenchulus reniformis* in the United States. Journal of Nematology 22:695-699.

HEFFES, T. P., P. L. COATES-BECKFORD, and D. G. HUTTON. 1990. Population development and effects of *Rotylenchulus reniformis* on growth of *Amaranthus viridis* and three cultivars of *Hibiscus sabdariffa*. Nematropica 20:95-98.

HEFFES, T. P., P. L. COATES-BECKFORD, and H. ROBOTHAM. 1992. Effects of *Meloidogyne incognita* and *Rotylenchulus reniformis* on growth and nutrient content of *Vigna unguiculata* and *Zea mays*. Nematropica 22:139-148.

HEYNS, J. 1976. *Rotylenchulus parvus*. C. I. H. descriptions of plant parasitic nematodes, Set 6, No. 83. Commonwealth Institute of Helminthology, St. Albans, Herts., England. 3 pp.

HILLOCKS, R. J., M. R. SIDDIQI, and E. B. KHONGA. 1995. Nematodes associated with subsistence crops in southern Malawi. Afro-Asian Journal of Nematology 5:14-19.

INSERRA, R. N. 1994. Tri-ology Technical Report 33(3):8. Nematology Section, Florida Department of Agriculture and Consumer Services, Gainesville, FL, U.S.A.

INSERRA, R. N., and L. W. DUNCAN. 1996. Host status of rough lemon to *Rotylenchulus reniformis*. Nematropica 26:87-90.

INSERRA, R. N., and R. A. DUNN. 1992. Effect of *Rotylenchulus reniformis* survival on nematode management in ornamental nurseries of southern Florida. Nematology Circular No. 199. Florida Department of Agriculture and Consumer Services, Gainesville, FL, U.S.A.

INSERRA, R. N., R. A. DUNN, R. McSORLEY, K. R. LANGDON, and A. Y. RICHMER. 1989. Weed hosts of *Rotylenchulus reniformis* in ornamental nurseries of southern Florida. Nematology Circular No. 171. Florida Department of Agriculture and Consumer Services, Gainesville, FL, U.S.A.

INSERRA, R. N., R. A. DUNN, and J. L. STARR. 1991. Regulatory implications of *Rotylenchulus reniformis* infestations in ornamental nurseries in Florida. Southern Nursery Digest 25:18-19.

INSERRA, R. N., R. A. DUNN, and N. VOVLAS. 1994. Host response of ornamental palms to *Rotylenchulus reniformis*. Journal of Nematology 26:737-743.

INSERRA, R. N., W. L. ROBINSON, and W. W. SMITH. 1995. Nematode parasites of daylily roots. Nematology Circular No. 211. Florida Department of Agriculture and Consumer Services: Gainesville.

INSERRA, R. N., and N. VOVLAS. 1980. The biology of *Rotylenchulus macrodoratus*. Journal of Nematology 12:97-102.

JONES, J. E., J. P. BEASLEY, J. I. DICKSON, and W. D. CALDWELL. 1988. Registration of four cotton germplasm lines with resistance to reniform and root-knot nematodes. Crop Science 28:199-200.

JONES, M. G. K., and V. H. DROPKIN. 1975. Cellular alterations induced in soybean roots by three endoparasitic nematodes. Physiological Plant Pathology 5:119-124.

KHADR, A. S., A. A. SALEM, and B. A. OTEIFA. 1972. Varietal susceptibility and significance of the reniform nematode *Rotylenchulus reniformis* in Fusarium wilt of cotton. Plant Disease Reporter 56:1040-1042.

KHAN, A. H., S. K. SAXENA, and I. MAHMOOD. 1984. Effect of different cropping sequences on the population of plant-parasitic nematodes. Pakistan Journal of Nematology 29:29-36.

KHAN, F. A. 1975. Some new host records of the reniform nematode in India. Indian Phytopathology 28:386-387.

KHAN, F. A. 1985. Hatching response of *Rotylenchulus reniformis* to root leachates of certain hosts and nonhosts. Revue de Nématologie 8:391-393.

KHAN, F. A., and A. M. KHAN. 1969. Reaction of certain economically important plants to *Rotylenchulus reniformis.* Pp. 8-9 *in* Proceedings, All India Nematology Symposium, New Delhi, August 21-22, 1969.

KHAN, F. A., and A. M. KHAN. 1973. Studies on the reniform nematode, *Rotylenchulus reniformis.* I. Host range and population changes. Indian Journal of Nematology 3:24-30.

KHAN, R. M., A. M. KHAN, and M. W. KHAN. 1985. Cellular changes in tomato roots following infection of reniform nematode. Pakistan Journal of Nematology 3:73-82.

KHAN, R. M., and M. W. KHAN. 1985. Histopathology of cauliflower roots infected with reniform nematode. Pakistan Journal of Nematology 3:83-85.

KHAN, T. A., and S. I. HUSAIN. 1988. Response of cowpea cultivars to *Rotylenchulus reniformis.* Nematropica 18:159-162.

KHAN, T. A., and S. I. HUSAIN. 1989a. Relative resistance of six cowpea cultivars as affected by the concomitance of two nematodes and a fungus. Nematologia Mediterranea 17:39-41.

KHAN, T. A., and S. I. HUSAIN. 1989b. Studies on the pathogenicity of *Meloidogyne incognita* and *Rotylenchulus reniformis* on cowpea (*Vigna unguiculata*) var. Pusa Barsati. Pakistan Journal of Nematology 7:109-113.

KHAN, T. A., and S. I. HUSAIN. 1990. Studies on the effect of interactions of variable inoculum levels of *Rotylenchulus reniformis, Meloidogyne incognita* and *Rhizoctonia solani* on cowpea. Current Nematology 1:49-52.

KIRBY, M. F. 1978. Reniform and root-knot nematodes on passionfruit in Fiji. Nematropica 8:21-25.

KLEYNHANS, K. P. N., E. VAN DEN BERG, A. SWART, M. MARAIS, and N. H. BUCKLEY. 1996. Plant nematodes in South Africa. Plant Protection Research Institute, Biosystematic Division, PB X134, Pretoria, South Africa. Pp. 61-62.

KO, M. P., and D. P. SCHMITT. 1993. Pineapple intercycle cover crops to reduce plant-parasitic nematode populations. Acta Horticulturae 334:373-382.

KONICEK, D. E. 1963. A plant parasitic nematode of the genus *Rotylenchulus* found in California. Phytopathology 53:1140 (Abstract).

KUMAR, A. C., P. R. K. VISWANATHAN, and G. I. D'SOUZA. 1971. A study on plant parasitic nematodes of certain commercial crops in coffee tracts of south India. Indian Coffee 35:222-224.

KUMAR, S., and C. V. SIVAKUMAR. 1981. Disease complex involving *Rotylenchulus reniformis* and *Rhizoctonia solani* in okra. Nematologia Mediterranea 9:145-149.

LAL, A., B. S. YADAV, and R. P. NANDWANA. 1976. A record of some new and known weed hosts of *Rotylenchulus reniformis* Linford & Oliveira, 1940 from Rajasthan. Indian Journal of Nematology 6:94-116.

LAMBERTI, F., and D. DANDRIA. 1979. Plant parasitic nematodes in the Maltese islands and the problems they cause. Phytopathologia Mediterranea 18:71-76.

LAWRENCE, G. W., and K. S. McLEAN. 1992. Host status and response of kenaf (*Hibiscus cannabinus*) to *Meloidogyne incognita* race 4, *M. javanica, Hoplolaimus magnistylus,* and *Rotylenchulus reniformis.* Nematropica 22:247-250.

LAWRENCE, G. W., and K. S. McLEAN. 1996. Reniform nematode and cotton production in Mississippi. Pp. 251-253 *in* Proceedings, National Cotton Council Beltwide Cotton Conferences, U.S.A.

LAWRENCE, G. W., G. L. WINDHAM, and K. S. McLEAN. 1991. Reniform nematode management in a corn-cotton rotation system. Phytopathology 81:1211 (Abstract).

LEHMAN, P. S. 1990. Tri-ology Technical Report 29(2):2-3. Nematology Section, Florida Department of Agriculture and Consumer Services, Gainesville, FL, U.S.A.

LEHMAN, P. S. 1995. Tri-ology Technical Report 34(2):4. Nematology Section, Florida Department of Agriculture and Consumer Services, Gainesville, FL, U.S.A.

LEHMAN, P. S., and R. N. INSERRA. 1990. Morphometric variation of *Rotylenchulus parvus* and *Rotylenchulus reniformis* populations in the southern United States. Soil and Crop Science Society of Florida Proceedings 19:220-226.

LIM, B. K., and M. B. CASTILLO. 1979. Screening soybeans for resistance to reniform nematode disease in the Philippines. Journal of Nematology 11:275-282.

LINFORD, M. B., and J. M. OLIVEIRA. 1940. *Rotylenchulus reniformis,* nov. gen., n. sp., nematode parasite of roots. Proceedings of the Helminthological Society of Washington 7:35-42.

LINFORD, M. B., and F. YAP. 1940. Some host plants of the reniform nematode in Hawaii. Proceedings of the Helminthological Society of Washington 7:42-44.

LOOF, P., and M. OOSTENBRINK. 1962. *Rotylenchulus borealis* n. sp. with a key to the species of *Rotylenchulus.* Nematologica 7:83-90.

LUC, M., and G. DE GUIRAN. 1960. Les nématodes associés aux plantes de l'ouest Africain. L'Agronomie Tropicale 15:434-449.

MACEDO, M. C. M. 1974. Susceptibilidade de cafeeiros ao nematoide reniforme. Solo 66:15-16.

MacGOWAN, J. B. 1989. Tri-ology Technical Report 28(12):1-3. Nematology Section, Florida Department of Agriculture and Consumer Services, Gainesville, FL, U.S.A.

MAHAPATRA, B. C., and N. N. PADHI. 1986. Pathogenicity and control of *Rotylenchulus reniformis* on *Cicer arietinum.* Nematologia Mediterranea 14:287-290.

MAKADIA, B. M., D. J. PATEL, D. K. JOGANI, and H. M. SHAH. 1987. Reactions of root-knot nematode resistant and susceptible cowpea varieties to reniform nematode, *Rotylenchulus reniformis.* Gujarat Agricultural University Research Journal 12:62-64.

MARTIN, W. J. 1960. The reniform nematode may be a serious pest of the sweetpotato. Plant Disease Reporter 44:216.

MARTIN, W. J., and W. BIRCHFIELD. 1955. Notes on plant parasitic nematodes in Louisiana. Plant Disease Reporter 39:3-4.

MARTIN, W. J., W. BIRCHFIELD, and T. P. HERNANDEZ. 1966. Sweet potato varietal reaction to the reniform nematode. Plant Disease Reporter 50:500-502.

MASSOUD, S. I., and A. I. GHORAB. 1988. Histopathological responses of clover roots infected with *Meloidogyne incognita, Heterodera daverti* and *Rotylenchulus reniformis.* Egyptian Journal of Phytopathology 20:79-85.

McGAWLEY, E. C., and C. OVERSTREET. 1995. Reproduction and pathological variation in populations of *Rotylenchulus reniformis.* Journal of Nematology 27:508 (Abstract).

McSORLEY, R. 1980. Effect of *Rotylenchulus reniformis* on snap bean and methods for control by oxamyl. Nematropica 10:89-95.

McSORLEY, R., S. K. O'HAIR, and J. L. PARRADO. 1983. Nematodes associated with the edible aroid genera *Xanthosoma* and *Colocasia* and their effects on yield. Nematropica 13:165-180.

McSORELY, R., and J. L. PARRADO. 1983. Influence of summer management strategies on nematode populations in a subtropical agroecosystem. Nematropica 13:1-8.

McSORLEY, R., J. L. PARRADO, and S. GOLDWEBER. 1981a. Plant parasitic nematodes associated with mango and relationship to tree condition. Nematropica 11:1-9.

McSORLEY, R., K. POHRONEZNY, and W. M. STALL. 1981b. Aspects of nematode control on snap bean with emphasis on the relationship between nematode density and plant damage. Proceedings of the Florida State Horticultural Society 94:134-136.

MEHTA, U. K., and P. R. SUNDARA. 1989. Reniform nematode, *Rotylenchulus reniformis* Linford and Oliveira, 1940, on roots of sugarcane, *Saccharum officinarum* L. FAO Plant Protection Bulletin 37:83-86.

MELTON, T. A., and N. T. POWELL. 1991. Effects of nematicides and cultivars on *Rotylenchulus reniformis* and flue-cured tobacco yield. Journal of Nematology 23:712-716.

MEREDITH, J. A., R. N. INSERRA, and D. MONZON DE FERNANDEZ. 1983. Parasitism of *Rotylenchulus reniformis* on soybean root *Rhizobium* nodules in Venezuela. Journal of Nematology 15:211-214.

MINTON, E. B. 1964. Population dynamics of seven nematode species and their effects on ten cotton varieties. Dissertation Abstracts 25:1478-1479.

MISHRA, S. D., and H. S. GAUR. 1981. Pathogenicity of *Meloidogyne incognita* and *Rotylenchulus reniformis* to mothbean, *Vigna aconitifolius* Jacq. Indian Journal of Nematology 11:228-230.

MONTASSER, S. A. 1986. Resistance in tomato cultivars to the reniform nematode *Rotylenchulus reniformis.* Pakistan Journal of Nematology 4:79-82.

MONTASSER, S. A., A. A. ALSAYED, and S. S. AHMED. 1992. Varietal response of potato to *Meloidogyne javanica* and *Rotylenchulus reniformis.* Annals of Agricultural Science, Moshtohor 30:607-614.

MUHAMMAD, N., and J. E. JONES. 1990. Genetics of resistance to reniform nematode in Upland cotton. Crop Science 30:13-16.

MURALIDARAN, R., and C. V. SIVAKUMAR. 1977. Susceptibility of varieties of cotton and wild species of *Gossypium* to the reniform nematode *Rotylenchulus reniformis.* Indian Journal of Nematology 5:116-118.

NAKASONO, K. 1973. Relationship between cultivation of *Tagetes* plants and changes in population of the reniform nematode, *Rotylenchulus reniformis.* Japanese Journal of Nematology 3:38-41.

NAKASONO, K. 1983. Studies on mophological and physio-ecologial variation of the reniform nematode, *Rotylenchulus reniformis* Linford and Oliveira, 1940 with an emphasis on differential geographical distribution of amphimictic and parthenogenetic populations in Japan. Bulletin of the National Institute of Agricultural Sciences, Japan 38:63-67.

NAYAK, D. K., B. N. ROUTARAY, and S. N. DAS. 1987. Relative susceptibility of some horsegram cultivars against reniform nematode, *Rotylenchulus reniformis.* International Nematology Network Newsletter 4:19-20.

NATH, R. P., M. G. HAIDAR, S. W. AKHTER, and H. PRASAD. 1976. Studies on the nematodes of vegetables in Bihar - I. Effect of the reniform nematode, *Rotylenchulus reniformis,* on *Trichosanthes dioica.* Indian Journal of Nematology 6:175-177.

NEAL, D. C. 1954. The reniform nematode and its relationship to the incidence of Fusarium wilt of cotton at Baton Rouge, Louisiana. Phytopathology 44:447-450.

OVERSTREET, C. 1996. Impact of reniform nematode on cotton production in the U.S.A. Nematropica 26:216 (Abstract).

OVERSTREET, C., and E. C. McGAWLEY. 1996. Current incidence of plant parasitic nematodes in Louisiana. Pp. 253-254 *in* Proceedings, National Cotton Council Beltwide Cotton Conferences, U.S.A.

PADHI, N. N., and R. P. MISRA. 1987. Pathologic reactions of French bean to the reniform nematode at varying levels of inoculation. Indian Journal of Nematology 17:128-129.

PANDA, M., and A. R. SESHADRI. 1979. Effect of initial inoculum level of *Rotylenchulus reniformis* on different growth attributes of cowpea, mungbean and urid. Indian Journal of Nematology 9:59-60.

PATEL, B. A., J. C. CHAVDA, S. T. PATEL, and D. J. PATEL. 1987. Reaction of some pigeonpea lines to reniform nematode (*Rotylenchulus reniformis*). International Pigeonpea Newsletter 6:57-59.

PATEL, B. A., J. C. CHAVDA, and D. J. PATEL. 1989a. Screening of certain greengram lines against reniform nematode, *Rotylenchulus reniformis.* International Nematology Network Newsletter 6:25-26.

PATEL, D. J. 1986. Histopathology of tobacco roots infected by *Rotylenchulus reniformis.* Pakistan Journal of Nematology 4:75-78.

PATEL, H. V., D. J. PATEL, and B. A. PATEL. 1989b. Reaction of papaya varieties to *Rotylenchulus reniformis.* International Nematology Network Newsletter 6:24.

PATEL, O. S., and N. A. THAKAR. 1986. Efficacy of some systemic chemicals in control of *Rotylenchulus reniformis* infecting mungbean. Indian Journal of Nematology 16:281-282.

PATEL, S. K., K. N. VYAS, and D. J. PATEL. 1988. Histological changes due to combined inoculation of two root-knot and reniform nematodes in tobacco. Pakistan Journal of Nematology 6:87-92.

PEACOCK, F. C. 1956a. The reniform nematode in the Gold Coast. Nature 177:489.

PEACOCK, F. C. 1956b. The reniform nematode in the Gold Coast. Nematologica 1:307-310.

PERRY, V. G., I. W. HUGHES, and E. A. MANUEL. 1962. Some plant nematodes of Bermuda. Soil and Crop Science Society of Florida Proceedings 22:135-138.

QUENEHERVE, P., F. DROB, and P. TOPART. 1995. Host status of some weeds to *Meloidogyne* spp., *Pratylenchus* spp., *Helicotylenchus* spp. and *Rotylenchulus reniformis* associated with vegetables cultivated in polytunnels in Martinique. Nematropica 25:149-157.

RADEWALD, J. D., and G. TAKESHITA. 1964. Desiccation studies on five species of plant-parasitic nematodes of Hawaii. Phytopathology 54:903-904.

RAZAK, A. R., and A. A. F. EVANS. 1976. An intracellular tube associated with feeding by *Rotylenchulus reniformis* on cowpea roots. Nematologica 22:182-189.

REBOIS, R. V. 1973. Effect of soil temperature on infectivity and development of *Rotylenchulus reniformis* on resistant and susceptible soybeans, *Glycine max.* Journal of Nematology 5:10-13.

REBOIS, R. V. 1980. Ultrastructure of a feeding peg and tube associated with *Rotylenchulus reniformis* in cotton. Nematologica 26:396-405.

REBOIS, R. V., B. J. ELDRIDGE, J. M. GOOD, and A. K. STONER. 1973. Tomato resistance and susceptibility to the reniform nematode. Plant Disease Reporter 57:169-172.

REBOIS, R. V., B. J. ELDRIDGE, and R. E. WEBB. 1978. *Rotylenchulus reniformis* parasitism of potatoes and its effect on yield. Plant Disease Reporter 62:520-523.

REBOIS, R. V., J. M. EPPS, and E. E. HARTWIG. 1970. Correlation of resistance in soybeans to *Heterodera glycines* and *Rotylenchulus reniformis.* Phytopathology 60:695-700.

REBOIS, R. V., W. C. JOHNSON, and E. J. CAIRNS. 1968. Resistance in soybeans, *Glycine max* Merr., to the reniform nematode. Crop Science 8:394-395.

REBOIS, R. V., P. A. MADDEN, and B. J. ELDRIDGE. 1975. Some ultrastructural changes induced in resistant and susceptible soybean roots following infection by *Rotylenchulus reniformis.* Journal of Nematology 7:122-139.

REBOIS, R. V., and R. E. WEBB. 1979. Reniform nematode resistance in potato clones. American Potato Journal 56:313-319.

RICHMOND, T. R. (ED.) 1968. Genetics and cytology of cotton, 1956-67. Southern Cooperative Series Bulletin 139. Cooperative State Research Service, USDA. Washington, D.C., U.S.A.

ROBBINS, R. T., L. RAKES, and C. R. ELKINS. 1994a. Reniform nematode reproduction and soybean yield of four soybean cultivars in Arkansas. Journal of Nematology 26:656-658.

ROBBINS, R. T., L. RAKES, and C. R. ELKINS. 1994b. Reproduction of the reniform nematode on thirty soybean cultivars. Journal of Nematology 26:659-664.

ROBINSON, A. F., C. M. HEALD, S. L. FLANAGAN, W. H. THAMES, and J. AMADOR. 1987. Geographical distributions of *Rotylenchulus reniformis, Meloidogyne incognita,* and *Tylenchulus semipenetrans* in the Lower Rio Grande Valley as related to soil texture and land use. Annals of Applied Nematology 1:20-25.

ROBINSON, A. F., and C. C. ORR. 1980. Histopathology of *Rotylenchulus reniformis* on sunflower. Journal of Nematology 12:84-85.

RODRIGUEZ-FUENTES, E. 1980. Supervivencia de *Rotylenchulus reniformis* Linford and Oliveira, 1940, sin la influencia del cultivo. Centro Agrícola, Revista Científica de la Facultad de Ciencias Agrícolas, Universidad Central, Las Villas, Cuba 7:67-74.

RODRIGUEZ-FUENTES, E., and J. AÑORGA-MORALES. 1977. Estudios sobre la reproducción partenogenética y el desarrollo post-embrional de *Rotylenchulus reniformis* Linford y Oliveira, 1940. Centro Agrícola, Revista Científica de la Facultad de Ciencias Agrícolas, Universidad Central, Las Villas, Cuba 4:49-55.

ROHRBACK, K. G., and W. J. APT. 1986. Nematode and disease problems of pineapple. Plant Disease 70:81-87.

ROMAN, J. 1964. Immunity of sugarcane to the reniform nematode. Journal of Agriculture of the University of Puerto Rico 48:162-163.

ROMAN, J., and L. GRULLON. 1975. Nematodes associated with sugarcane in the Dominican Republic. Journal of Agriculture of the University of Puerto Rico 59:138-140.

ROUTARAY, B. N., H. SAHOO, and S. N. DAS. 1986. Evaluation of greengram and blackgram varieties against reniform nematode *Rotylenchulus reniformis.* Indian Journal of Nematology 16:27-29.

ROUTARAY, B. N., H. SAHOO, and S. N. DAS. 1988. Evaluation of some chilli cultivars against *Meloidogyne incognita* and *Rotylenchulus reniformis.* Journal of the Indian Botanical Society 67:220-221.

RUSH, D. E., W. S. GAZAWAY, and J. R. AKRIDGE. 1996. Effect of rotation on reniform nematode control in cotton. P. 247 *in* Proceedings, National Cotton Council Beltwide Cotton Conferences, U.S.A.

RYSS, A. 1992. Some records of plant parasitic nematodes (Nematoda, Tylenchida) from Estonia. Eesti Teaduste Akadeemia Toimetised, Bioloogia 41:72-76.

SAHOO, H., and N. N. PADHI. 1986. Susceptibility of plants to the reniform nematode, *Rotylenchulus reniformis.* Indian Journal of Nematology 16:97-98.

SAHOO, H., B. N. ROUTARAY, and S. N. DAS. 1986. Evaluation of bengalgram varieties against reniform nematode, *Rotylenchulus reniformis.* Journal of the Indian Botanical Society 65:86-89.

SCHENCK, S. 1990. Correlations of *Rotylenchulus reniformis* population densities with 1,3-dichloropropene dosage rate and pineapple yields. Journal of Nematology 22:735-739.

SCHENCK, S., and D. SCHENCK. 1994. Determination of a management strategy for nematode pests of Hawaiian coffee. International Journal of Pest Management 40:283-285.

SCHNEIDER, R. C., J. ZHANG, M. M. ANDERS, D. P. BARTHOLOMEW, and E. P. CASWELL-CHEN. 1992. Nematicide efficacy, root growth and fruit yield in drip-irrigated pineapple parasitized by *Rotylenchulus reniformis.* Journal of Nematology 24:540-547.

SCOTTO LA MASSESE, C. 1973. Nouvel hôte et nouvelle localisation de *Rotylenchulus macrodoratus* (Dasgupta, Raski, and Sher, 1968). Nematologia Mediterranea 1:55-56.

SEHGAL, M., and H. S. GAUR. 1988. Survival and infectivity of the reniform nematode, *Rotylenchulus reniformis,* in relation to moisture stress in soil without host. Indian Journal of Nematology 18:49-54.

SEHGAL, M., and H. S. GAUR. 1989. Effect of the rate of soil moisture loss on the survival, infectivity and development of *Rotylenchulus reniformis,* the reniform nematode. Pakistan Journal of Nematology 7:83-90.

SHARMA, S. B., P. REMANANDAN, and D. McDONALD. 1993. Resistance to *Meloidogyne javanica* and *Rotylenchulus reniformis* in wild relatives of pigeonpea. Journal of Nematology 25:824-829.

SHEPHERD, R. L. 1983. Indices of resistance to root-knot nematodes for primitive race stocks of Upland cotton. Agricultural Research Service Manual ARM-S-33. U. S. Government Printing Office: Washington, DC., U.S.A.

SHER, S. A. 1961. Revision of Hoplolaiminae (Nematoda) I. Classification of nominal genera and nominal species. Nematologica 24:110-118.

SIDDIQUI, M. A., and M. M. ALAM. 1987. Control of phytonematodes by mix-culture of *Tagetes lucida.* Indian Journal of Plant Pathology 5:73-78.

SIKORA, R. A., and N. GRECO. 1990. Nematode parasites of food legumes. Pp. 181-235 *in* M. Luc, R. A. Sikora, and J. Bridge, eds. Plant Parasitic Nematodes in Subtropical and Tropical Agriculture. C.A.B. International Institute of Parasitology, Wallingford, Oxon, U.K.

SINGH, N. D. 1974. Some host plants of the reniform nematode in Trinidad. Pp. 119-125 *in* C. W. D. Brathwaite, R. H. Phelps, and F. D. Bennett, eds. Proceedings, Symposium on Protection of Horticultural Crops in the Caribbean. University of the West Indies, St. Augustine, Trinidad.

SINGH, N. D. 1975. Studies on selected hosts of *Rotylenchulus reniformis* and its pathogenicity to soybean (*Glycine max*). Nematropica 5:46-51.

SINGH, N. D., and K. M. FARRELL. 1972. Occurrence of *Rotylenchulus reniformis* in Trinidad, West Indies. Plant Disease Reporter 56:551.

SIVAKUMAR, C. V., P. LAKSHMANAN, and M. BALASUBRAMANIAN. 1979. Interaction of a nonhost plant (*Capsicum annuum*) and certain systemic nematicides in population decline of *Rotylenchulus reniformis.* Revue de Nématologie 2:165-168.

SIVAKUMAR, C. V., and A. R. SESHADRI. 1971. Life history of the reniform nematode *Rotylenchulus reniformis* Linford and Oliveira, 1940. Indian Journal of Nematology 1:7-20.

SIVAKUMAR, C. V., and A. R. SEHSHADRI. 1972. Histopathology of infection by the reniform nematode, *Rotylenchulus reniformis* Linford & Oliveira, 1940 on castor, papaya and tomato. Indian Journal of Nematology 2:173-181.

SOARES DA SILVA, G., S. FERRAZ, and J. MAIA DOS SANTOS. 1989. Resistencia de especies de *Crotalaria* a *Rotylenchulus reniformis.* Nematologia Brasileira 13:87-92.

SRIVASTAVA, A. N., and C. L. SETHI. 1986. Seasonal population fluctuations of *Heterodera zeae, Rotylenchulus reniformis* and *Tylenchorhynchus vulgaris* in maize-cowpea-wheat rotation. Indian Journal of Nematology 16:16-18.

STARR, J. L. 1991. *Rotylenchulus reniformis* on greenhouse-grown foliage plants: Host range and sources of inoculum. Journal of Nematology 23:634-638.

STARR, J. L., C. M. HEALD, A. F. ROBINSON, R. G. SMITH, and J. P. KRAUSZ. 1993. *Meloidogyne incognita* and *Rotylenchulus reniformis* and associated soil textures from some cotton production areas of Texas. Journal of Nematology 25:895-899.

STEINER, G. 1949. Plant nematodes the grower should know. Soil and Crop Science Society of Florida Proceedings (1942) 4:72-117.

STOKES, D. E. 1982. A reniform nematode, *Rotylenchulus parvus.* Nematology Circular No. 91. Florida Department of Agriculture and Consumer Services, Gainesville, FL, U.S.A.

STOYANOV, D. 1967. Additions to host records of *Meloidogyne* sp., *Helicotylenchus multicinctus* and *Rotylenchulus reniformis.* Nematologica 13:173.

STOYANOV, D. 1971. Some nematological problems in citrus crops in Cuba. Revista de Agricultura, Cuba 4:65-71.

SUAREZ, H. Z., M. S. GONZALEZ, L. S. ROSALES, and V. TELECHEA. 1993. Alteraciones histológicas en *Passiflora edulis* f. sp. *flavicarpa* inducidas por *Rotylenchulus reniformis.* Fitopatología Venezolana 6:11-14.

SUBRAMANIAN, S., G. RAJENDRAN, and S. VADIVELU. 1993. Reaction of some tomato genotypes to the reniform nematode *Rotylenchulus reniformis.* Indian Journal of Nematology 23:123-124.

SUD, U. C., K. S. VARAPRASAD, A. R. SESHADRI, and K. K. KHER. 1984. Relationship between initial densities of *Rotylenchulus reniformis* and damage to cotton with a fit to Seinhorst's curves. Indian Journal of Nematology 14:148-151.

TAHA, A. H., and A. S. KASSAB. 1979. The histopathological reactions of *Vigna sinensis* to separate and concomitant parasitism by *Meloidogyne javanica* and *Rotylenchulus reniformis.* Journal of Nematology 11:117-123.

TAHA, A. H. Y., and S. A. SULTAN. 1979. Cellular response of grape seedlings to *Rotylenchulus reniformis* and *Tylenchulus semipenetrans* infections. Nematologia Mediterranea 7:45-50.

TAYLOR, D. P., C. NETSCHER, and G. GERMANI. 1978. *Adansonia digitata* (Baobab), a newly discovered host for *Meloidogyne* sp. and *Rotylenchulus reniformis*: Agricultural implications. Plant Disease Reporter 62:276-277.

THAKAR, N. A., and C. C. PATEL. 1985. Screening of few cowpea varieties against reniform nematode, *Rotylenchulus reniformis* Linford and Oliveira, 1940. Indian Journal of Nematology 14:204.

THAKAR, N. A., and B. S. YADAV. 1985. Screening pigeonpeas for their resistance to reniform nematode. International Pigeonpea Newsletter 4:42-43.

THAKAR, N. A., and B. S. YADAV. 1986. Role of total phenols in pigeonpea resistance to reniform nematode. Indian Journal of Nematology 16:261-263.

THAKAR, N. A., and B. S. YADAV. 1987. Evaluation of pigeonpea varieties/lines for resistance against the reniform nematode. Indian Journal of Nematology 17:132-133.

THOMAS, R. J., and C. A. CLARK. 1983. Effects of concomitant development on reproduction of *Meloidogyne incognita* and *Rotylenchulus reniformis* on sweet potato. Journal of Nematology 15:215-221.

THORNE, G. 1961. Principles of Nematology. McGraw-Hill, New York, NY, U.S.A.

TIMM, R. W. 1956. The reniform nematode, a root parasite of *Vicia faba*. Pakistan Review of Agriculture 2:135.

TSAI, B. Y., and W. J. APT. 1979. Anhydrobiosis of the reniform nematode: Survival and coiling. Journal of Nematology 11:316 (Abstract).

VALDEZ, R. B. 1968. Stubby roots of coffee seedlings caused by *Rotylenchulus reniformis*. Philippine Agriculturist 51:672-679.

VAN DEN BERG, E. 1990. Two new and one known species of the Tylenchoidea (Nemata) from southern Africa. Phytophylactica 22:23-34.

VAN DEN BERG, E., and V. W. SPAULL. 1981. *Rotylenchulus* species found associated with sugarcane in South Africa with a description of *R. sacchari* sp. n. (Nematoda: Rotylenchulinae). Phytophylactica 13:43-47.

VAN DEN OEVER, H. A. M., and E. MANGANE. 1992. A survey of nematodes on various crops in Mozambique. Afro-Asian Journal of Nematology 2:74-79.

VAN WEERDT, L. G., W. BIRCHFIELD, and R. P. ESSER. 1959. Observations on some subtropical plant parasitic nematodes in Florida. Soil and Crop Science Society of Florida Proceedings 19:443-451.

VARAPRASAD, K. S. 1986. *Rotylenchulus reniformis* Linford and Oliveira, 1940—A comprehensive account of systematics, biology & management. Pp. 194-210 *in* G. Swarup and D. R. Dasgupta, eds. Plant Parasitic Nematodes of India, Problems and Progress. Indian Agricultural Research Institute, New Dehli, India.

VARAPRASAD, K. S., U. C. SUD, and G. SWARUP. 1987. Relationship between *Rotylenchulus reniformis* densities and host damage with reference to tolerance levels. Indian Journal of Nematology 17:11-16.

VOVLAS, N. 1983. Gall formation on *Pistacia vera* by *Rotylenchulus macrodoratus*. Journal of Nematology 15:148-150.

VOVLAS, N., E. COHN, and R. N. INSERRA. 1985. Histological changes induced by *Rotylenchulus borealis* on corn and sweet potato and by *R. parvus* on sugarcane. Revue de Nématologie 8:125-130.

VOVLAS, N., and H. M. R. K. EKANAYAKE. 1985. Histological alterations induced by *Rotylenchulus reniformis* alone or simultaneously with *Meloidogyne incognita* on banana roots. Nematropica 15:9-17.

VOVLAS, N., and R. N. INSERRA. 1976. Istopatologia di radici di olivo infestate da *Rotylenchulus macrodoratus* Dasgupta, Raski *et* Sher. Nematologia Mediterranea 4:223-230.

VOVLAS, N., and R. N. INSERRA. 1982. Biological relationship of *Rotylenchulus borealis* on several plant cultivars. Journal of Nematology 14:373-377.

VOVLAS, N., and F. LAMBERTI. 1990. Histological alterations induced by *Rotylenchulus reniformis* on *Coffea arabica* roots. Nematologia Mediterranea 18:77-81.

VOVLAS, N., and E. VLACHOPOULOS. 1991. Parasitism of the Mediterranean reniform nematode *Rotylenchulus macrodoratus* on grape in Crete, Greece. Ciencia Biologica, Ecology and Systematics 11:1-6.

WALTERS, S. A., and K. R. BARKER. 1993. Reproductive and damage potentials of two populations of *Rotylenchulus reniformis* on sweet potato and related comparisons with *Meloidogyne javanica* on tomato. Journal of Nematology 25:830-835.

WILLIAMS, J. D. 1960. Studies on the nematode soil fauna of Mauritius. Tylenchoidea (Partim). Mauritius Sugar Industry Research Institute 4:1-30.

WILLIAMS, C., D. F. GILMAN, D. S. FONTENOT, and W. BIRCHFIELD. 1981. Inheritance of reaction to the reniform nematode in soybean. Crop Science 21:93-94.

WINDHAM, G. L., and G. W. LAWRENCE. 1992. Host status of commercial maize hybrids to *Rotylenchulus reniformis*. Journal of Nematology 24:745-748.

WOMERSLEY, C., and C. CHING. 1989. Natural dehydration regimes as a prerequisite for the successful induction of anhydrobiosis in the nematode *Rotylenchulus reniformis*. Journal of Experimental Biology 143:359-372.

YASSIN, M. Y., and A. E. ISMAIL. 1993. Effect of *Zinnia elegans* as a mix-crop along with tomato against *Meloidogyne incognita* and *Rotylenchulus reniformis*. Pakistan Journal of Nematology 11:31-35.

YIK, C.-P., and W. BIRCHFIELD. 1984. Resistant germplasm in *Gossypium* species and related plants to *Rotylenchulus reniformis*. Journal of Nematology 16:146-153.

Received: *3.VI.1997* *Accepted for publication:* *1.X.1997*

Recibido: *Aceptado para publicación:*